

RAILWAY WONDERS OF THE WORLD



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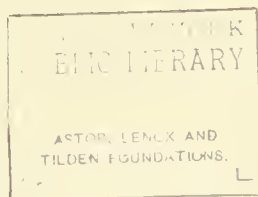
Talbot 8562

Railway Wonders of the World

THE CLARET CLAYTON'S ROOM
DOOR CLAYTON CENTER
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TAKING UP WATER.

Railway Wonders of the World

By

Frederick A. Talbot

Author of "The Railway Conquest of the World," "Motor-Cars and Their Story,"
"The New Garden of Canada," "The Making of a Great Canadian Railway," etc. etc.

Illustrated with Colour
Plates and Photographs



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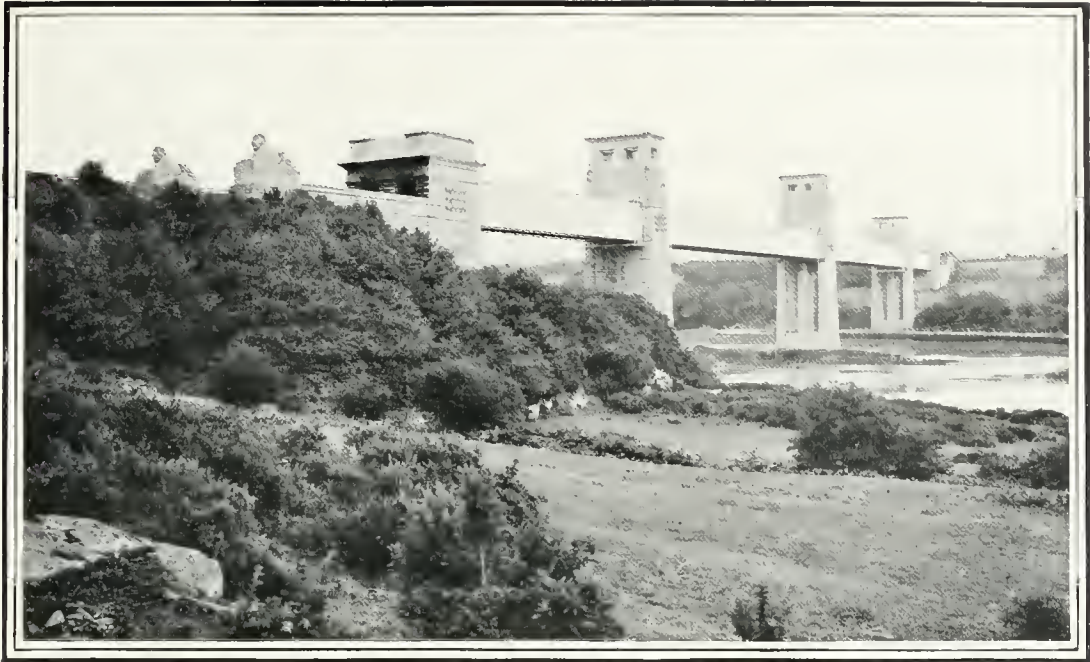
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Photograph supplied by the London and North Western Railway.

THE TUBULAR BRIDGE, DESIGNED BY STEPHENSON, OVER THE MENAI STRAITS.

The World's Most Famous Railway

HOW THE LONDON AND NORTH WESTERN LINE WAS FOUNDED AND
HAS DEVELOPED



PROBABLY no other steel highway is so famous throughout the world as that known to-day as the London and North Western Railway. While, as an entity, it represents a combination of some fifty individual systems, it is interesting historically because its nucleus was the celebrated Liverpool and Manchester Railway, which was opened for traffic on September 15th, 1825, and on which the historic "Rocket" carried off the first prize of £500 in the Rainhill locomotive trials. It was this competition and its startling results that opened the eyes of the various countries to the possibilities of the railway and steam locomotive, and which precipi-

tated the railway building fever that ran like wildfire through the five continents.

While the operation of this pioneer line demonstrated the revolution that was destined to be wrought by this means of communication, the construction of the thirty miles between the two great commercial centres of Lancashire also brought home the fact that the railway builder, in his efforts to cleave a narrow passage for the ribbon of steel, would have to be prepared to be thrown against baffling obstacles which would tax his ingenuity, resourcefulness and determination to a supreme degree. Seven miles west of Manchester, and extending over twelve square miles, is the morass known as Chat Moss. The railway was plotted to run across it. At first, owing

to the fact that extensive drainage schemes had been carried out, it was thought that the bog would not offer any serious difficulties, but when the builders came to grips with it, they soon ascertained that the statements concerning its character and the obstruction it would offer to their advance were by no means over-estimated. Robert Stephenson, who, owing to failing health, had gone to South America to examine and report upon some gold and silver mines, received an urgent message from his father to come home and participate in the building of this railway. He reached home in December, 1827, and at once grappled with the problems which had arisen.

This brought him into touch with railway engineering in the field, and he established his name as a constructional engineer by the ingenuity and fertility he displayed in subjugating the treacherous Chat Moss. As it was impossible to build up an embankment merely by the discharge of spoil, since the latter immediately sank into the bog's slimy, unstable mass, he conceived the idea of laying the earthworks upon a brushwood foundation. He fashioned a substantial mattress of hurdles, interlaced with heather and tree boughs, which was laid upon the surface of the bog, and upon which the spoil was dumped. Under the superimposed weight the mattress sank deeper and deeper into the morass, until it gained a point beyond which it would not move. The embankment was as firm and as solid as if it were resting upon a rock, and inasmuch as the submerged mattress was certain to become stronger as time passed, owing to its becoming water-logged and assuming the character of bog-oak, it offered a complete solution of the teasing problem. Robert Stephenson's method of conquering the bog has never been superseded, for the simple reason that no other more efficient and inexpensive method has been discovered. The tundra of Asia, the muskeg

of North America, and the swamps of South America—all are "corduroyed," as this recourse to mattresses is termed, in order to carry the weight of a railway permanent way.

As the promoters of the Liverpool and Manchester Railway were engaged upon a pioneer undertaking, and were quite ignorant of the revenue-earning capabilities of the railway, they were extremely modest in their prophecies concerning traffic earnings. They estimated that the passenger business would bring in £10,000 and the movement of goods about £50,000 respectively, per annum, making a total of £60,000. They were startled by the results of the first year's operations, which amounted to £101,829, of which £80,000 accrued from the goods traffic. Is it surprising that such a result of the first year's working of the first commercial railway should have fired the imaginations of other promoters, and created innumerable "castles in the air"—dreams which were not shattered until the pricking of the railway bubble a quarter of a century later.

When the Liverpool and Manchester Railway had settled down, and had become an assured success, other small systems grew up around it. Among these was a short line, four and a half miles in length, which, branching from the main line, linked up with Warrington. Owing to Robert Stephenson's success with the parent line, he was entrusted with this work. Another company, the Grand Junction Railway, secured the requisite Parliamentary sanction to continue this Warrington branch to the south through Crewe to Birmingham. In the same year was granted permission also to build a railway 112½ miles in length from London to Birmingham. At the latter point it was to connect up with the Grand Junction Railway, so that through and direct communication would be offered between the Metropolis, Manchester and

**Estimated
Earnings.**

**Other
Ventures.**

**Conquering
Chat Moss.**

Liverpool. Robert Stephenson was entrusted with the survey of the London to Birmingham section, and afterwards became the chief engineer to the undertaking. Under his direction the first turf was cut at Chalk Farm on June 1st, 1834, and work was prosecuted so vigorously that the north was in railway touch with the Metropolis on September 20th, 1838.

But although the 112 miles to Birmingham were completed within such a short time, it must not be inferred that the work was straightforward, easy, and free from harassing difficulty. Far from it. The building of the Liverpool and Manchester line, despite Chat Moss and the heavy excavation in

Olive Cutting, was child's play in comparison with the London and Birmingham Railway. The cost of construction was based upon that of the former line; contractors regarded the undertaking in a similar light. It was impossible to do otherwise, seeing that there was no other work upon which to base prices. The contractors entered upon

their various tasks light-heartedly, but many, before they had proceeded far, became disillusioned, and had good occasion to regret their temerity. Some went down



Photograph by permission of the London and North Western Railway.

THE MAIN SHAFT IN THE KILSBY TUNNEL.

This work, owing to water trouble, proved the most difficult and expensive on the whole system.

into financial disaster; others cut their losses and retired discomfited from the scene; only the more determined pushed forward with a grim pertinacity so as to win out. Estimates were exceeded on every side, because the unexpected cropped up at every turn.

In order to reach Rugby the location of the line cut under the Kilsby Ridge. A



THE OLD AND

Full size working model of Stephenson's "Rocket," which won the £500 prize at Rainhill in 1830,



Photograph by permission of the London and North Western Railway.

THE NEW.

beside the 5,000th engine of the London and North Western Railway, built at the Crewe works in 1911.

tunnel 2,423 yards in length was inevitable. It seemed a straightforward job, because the borings which were driven in the customary manner, to determine the geological formation through which the bore was to extend, did not present any abnormalities. So the contractor estimated that he could complete the task for £99,000. Considering that up to this time a tunnel exceeding half-a-mile in length never had been attempted, the contractor certainly was daring and plucky to assume such a responsibility. It was decided to drive the tunnel from each end, and also north and south of two shafts, which were to be sunk from the ridge to the requisite level, and which were to be completed as ventilating shafts.

The contractor started operations in June, 1835, but ere many weeks had passed he learned to his dismay that the borings were completely unreliable. When he came to sink his shafts through what he had been led to expect to be sound earth and rock, he stumbled against slippery shale, quicksand and water, of which, strange to say, no inkling had been given in the borings, as they had missed these treacherous spots. The contractor persevered, hoping against hope that he would get through this treacherous strata as he sank his second shaft deeper, but after nine months' heartbreaking disappointments and fighting against overwhelming odds, he threw up the job.

The Kilsby Tunnel became a nightmare. The water trouble scared every other contractor; not one could be induced to quote a revised price for its completion. Accordingly, the railway company was forced to take it over. Robert Stephenson came upon the scene, surveyed the prospect, and finally came to the conclusion that the water trouble was probably quite local; was not fed by subterranean springs, and that, provided adequate pumping plant was erected, the shaft could be

pumped dry. He set up powerful steam-pumps and sank wells near the located line for the tunnel for the purpose of drawing the water away from the main shaft. In all, eighteen of these subsidiary shafts, or wells, were sunk, and with pumps capable of coping with 1,800 gallons per minute, the water difficulty was overcome, after a tedious battle lasting nine months. Bearing in mind the imperfect appliances available in those days, and that this was the first large railway tunnel-boring task which had been attempted, one cannot but admire the perseverance, dogged determination, and resourcefulness of Robert Stephenson and his assistants.

By the aid of a small army of 1,300 navvies, who toiled day and night incessantly, the tunnel was completed by October, 1838—a remarkable performance all things considered, especially when on one or two occasions the working forces received startling frights. Thus, in November, 1836, while the men were at work in the tunnel, there was a sudden and violent inrush of water. A stampede ensued, and the work appeared to be doomed. But examination proved that the incursion was limited. Although the workings were flooded, the men were able to continue their work. Large rafts were fashioned, on which the navvies and the requisite material were floated in and out of the tunnel, often at extreme risk, owing to the ungainly nature of the argosies and the difficulty of manipulating them in the darkness.

Owing to the treacherous character of the earth through which the bore was driven, the tunnel had to be lined throughout, and for this purpose 30,000,000 bricks were used. The two shafts which are used for ventilating purposes are each 60 feet in diameter, by 130 and 60 feet in depth respectively. By the time the rails were laid, the Kilsby Tunnel had run away with over £300,000—over three times as much as the original contract.

**Cost of
the Tunnel.**

At first the three companies which offered railway communication between London, Manchester and Liverpool promised to work harmoniously together, but in reality differences of opinion arose, and soon they were at daggers drawn. In order to provide a more direct route between Birmingham and Manchester than that offered by the Grand Junction Railway another company—the Manchester and Birmingham Railway—was born. This line never got any farther than Crewe in its construction out of Manchester. As the railway boom was setting in very strongly, and projects for meshing the whole of the British islands were being outlined every hour, the London and Birmingham Railway concluded that it would be able to make a more beneficial bargain with one or more of the newer schemes, and so flouted the Grand Junction Railway. The latter, fearing competition, at once devoted its energies to entrenching its position. It amalgamated itself with the Liverpool and Manchester, as well as numerous other lines, and this consolidation of interests rendered it a very formidable force to attack. Then it determined to carry the war into the enemy's camp. It prepared the plans for a railway running from Birmingham, via Warwick and Leamington, to a point near Oxford, where it would be able to effect a junction with the Great Western Railway. The latter, in return for giving the Grand Junction Railway entrance to London, was to secure the right to penetrate to Liverpool and Manchester.

The London and Birmingham Railway viewed this move with the greatest anxiety, as the greater part of its traffic would be filched away, and it would be surrounded by hostile interests. Thereupon the directors, after a solemn discussion of the outlook, decided to recede from their untenable hostile position, made overtures to the Grand Junction Railway, and suggested

that the two opposing forces should settle their differences and combine. The negotiations proved successful, and in 1846 the union was completed, the different concerns being bound into a homogeneous whole under the title of the London and North Western Railway.

When the first railways forming this system were taken in hand, the engineers, owing to lack of experience, generally clung to the theory that a locomotive would not be able to work by adhesion purely and simply over gradients exceeding about 1 in 330. Accordingly, the lines between London and Manchester were plotted so as to conform with this prevailing opinion. This lack of knowledge proved a fortunate circumstance in the long run, inasmuch as the company has been spared that costly realignment and reconstruction which has harassed other railways so sorely, owing to the adverse influence exerted by the heavy grades in their original lines.

Taken on the whole, the Birmingham section of the London and North Western Railway is one of the most level lines in the world, and **The Gradients.** is conducive to high speeds and economical operation. There is no bank exceeding 16 feet per mile—a rise which is so slight as to be almost negligible—while, owing to the care displayed by Stephenson in the original survey, the maximum difference in level between the highest and lowest parts of the line is only 308 feet. To-day, owing to the care which has been bestowed upon its up-keep, its permanent way cannot be rivalled; indeed, it has been taken as a pattern in other large undertakings throughout the world, notably by President Cassatt when he undertook the remodelling of the Pennsylvania Railway, and by President Hays when he embarked upon the construction of the Grand Trunk Pacific across Canada.

The general belief that a rise of 1 in 330 represented the maximum permissible for working by steam provoked a curious

**Formation
of the
L. & N.W.R.**

situation upon the section of the line between Euston terminus and Camden Town. Although the surveyors struggled hard, they found it absolutely impossible, owing to physical configuration, to secure

method of signalling the engineman in the winding-house, to notify him when to start his plant, had to be devised. The train was connected to the winding rope by means of a messenger, and when all was



Photograph by permission of the London and North Western Railway.

THE FAMOUS OLIVE CUTTING ON THE LIVERPOOL AND MANCHESTER RAILWAY, NOW FORMING PART OF THE LONDON AND NORTH WESTERN SYSTEM.

a rise of less than 1 in 70 between the two points. They made no attempt to work it by adhesion. Instead, all trains proceeding out of Euston were assisted as far as Camden Town by a cable, which was hitched on to the train and wound in by a stationary winding plant, comprising two engines placed underground at Camden Town. They were of 60 nominal horsepower, and the main pulleys had a diameter of 20 feet. The rope was about 13,000 feet in length, and cost over £450.

The system of operating this cable incline was quite in keeping with the times. As they were pre-electric days, another

ready, a lever, connected to a bell having its edge submerged in water, and suspended over an inverted bell-mouth forming the end of a tube, was depressed sharply. This action caused the air within the bell to be driven downwards through the tube, which extended from the terminus to the engine-house. At the latter point the air-tube was connected to a large whistle—virtually an organ-pipe—and the puff of air sent through the pipe produced a blast on the whistle. Owing to the distance which the air had to travel about four seconds elapsed in transmitting the signal. The winding engine was set in motion, and the

train attached thereto was hauled up the incline slowly. When the top of the bank was reached, the official on the train dexterously cast off the messenger without stopping the winding-engines. At times there was a miscalculation, and then the hauling machinery had to be stopped. The

were used. However, the stone blocks were found to make the road hard and uncomfortable, and inflicted severe wear and tear both upon the track and rolling stock. On the other hand, the stretch of line laid with wooden sleepers was found to be more comfortable, easier, and reduced mainten-



THE RUNCORN BRIDGE OVER THE RIVER MERSEY.

It is a lattice girder structure comprising three main spans each of 305 feet, with the rails 75 feet above the waterway.

haulage of the train by this system occupied from three to four minutes. Needless to say, when the locomotive engineers were able to evolve more powerful engines, and experience proved that the incline could be worked by adhesion, the winding system was abandoned.

When the line was first built, the metals were laid on stone blocks, of which 152,000 tons were used upon the 112 miles out of London, at a cost of £180,000. A similar practice had been adopted on the Liverpool and Manchester Railway, where the permanent way rested upon a solid foundation, although on those parts where somewhat soft land was encountered wooden sleepers

were used. Accordingly, after lying for a short while, the stone blocks between London and Birmingham were removed in favour of wooden sleepers.

From the day when the Liverpool and Manchester, the Grand Junction, and the London and Birmingham Railways were fused into one organisation, the principle of acquiring other individual roads was pursued. Thus, not only was competition eliminated, but the field of operations was widened very considerably. The London and North Western system to-day is in reality a combination of about sixty different railways throughout the Midlands, Wales, and the North of England to the

Border. A prudent policy of constructional extension also was followed, so that to-day the ramifications of the undertaking represent a network of some 2,000 miles.

Taken on the whole, the system does not possess many important works which under present conditions would rank as startling pieces of engineering, although in the early days many achievements created intense interest, and were regarded as marvels of human activity. The Kilsby Tunnel represents, perhaps, the most interesting illustration of tunnel-boring, owing to the abnormal difficulties which were encountered, while the tubular bridge across the Menai Straits, although subsequently eclipsed in point of length and importance by other similar structures, never has lost its fascinating interest, inasmuch as it was the first work of its class.

This bridge, 1,510 feet in length, comprises two immense rectangular tubes—one for each set of metals—
The Menai Bridge. through which the trains pass.

It was designed by Robert Stephenson, and was commenced in 1845. There are four spans, two each of 460 feet and two each of 230 feet, supported on masonry piers, giving a clearance of 103 feet 9 inches between the under side of the tubes and the water at high spring tides. At the ends the tubes are 23 feet in depth by 30 feet deep at the centre. The most interesting feature was in connection with their construction and setting in position in the days when facilities were slender and equipment of an indifferent character. A special plant of an elaborate, ingenious and expensive nature was set up for the work. While the erection of the piers was in progress, the construction of the box-tube spans was carried out on the banks of the Straits. When completed, the tubes were transferred to pontoons, and were floated to the site when the water was at high tide. By means of capstans and ropes the pontoons were warped into position between the piers until the ends of the

tubes were brought dead into position in grooves in the masonry, where they were made fast. As the tide fell, the pontoons dropped clear of their loads, leaving the tubes resting on their seats.

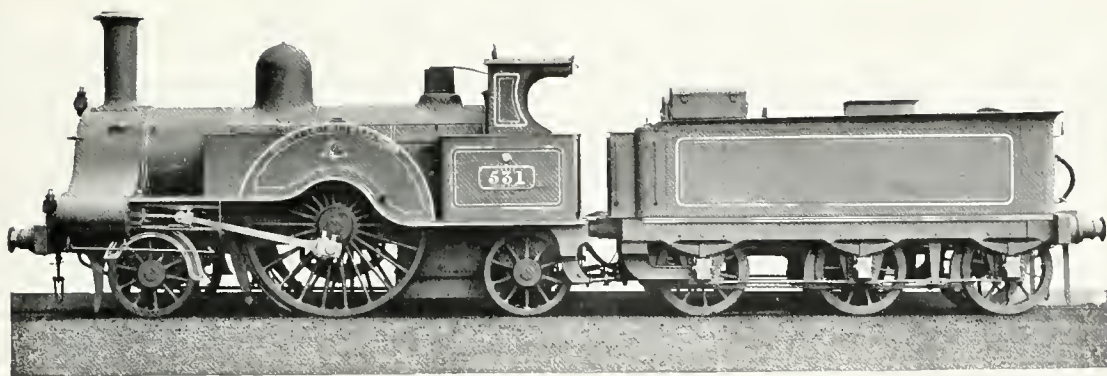
The tubes were then raised by the aid of a huge overhead hydraulic press, which by means of chains lifted them

6 feet at a time, the masonry being completed beneath as rapidly as possible after each lift. **How the Tubes were Raised.**

As the links of the chain could be withdrawn as required, having been made specially for this purpose, after each lift the chain was shortened, and the plunger of the hydraulic press permitted to descend. The shortened chain was then re-attached to the metallic work, and the ram of the plunger forced out again, lifting the mass a further 6 feet, to permit the masonry to be continued upwards a similar height. This cycle of operations was continued until the tubes were brought to the required level, the chains and plunger being called upon to handle, in this way, a maximum weight of 1,144 tons. The total weight of iron worked into the tubes is about 10,375 tons, and the walls present a superficies of 1,219,680 square feet for painting. As the tubes are continuous from end to end, they stretch about 6 inches in summer, under the influences of higher temperature.

The bridge was completed within the short space of five years, the first train passing through in 1850. Robert Stephenson adopted a similar bridge to span the River St. Lawrence at Montreal, for the Grand Trunk Railway of Canada. This, however, was a far larger undertaking. Two bridges of this type were built by him in Egypt, but in this latter instance the trains did not run through the bridge, but along the top deck of the rectangular tube.

Although the original stretches of the London and North Western Railway are very flat, and conducive to the fast and economical movement of traffic, the extensions of the system into Wales and north



THE "LADY OF THE LAKE."
Built in 1858. The driving wheel is 90 inches diameter.



THE "CHARLES DICKENS,"
which covered 2,000,000 miles—the world's record for a locomotive.



THE "HARDWICKE,"
which created a record in the "Race to the North" (1895) by running from Crewe to Carlisle—141 miles—at an average speed of 67.2 miles per hour.



Photographs by permission of the London and North Western Railway.

THE "IONIC,"
which hauled a train from London to Carlisle—299 miles—without a stop.
SOME FAMOUS LONDON AND NORTH WESTERN LOCOMOTIVES.

of Manchester to Carlisle proved far more difficult and expensive to build, bearing in mind the considerations of easy grade. On the main line to Scotland the ascent of Shap Fell to the summit level of 914 feet above the sea is heavy, averaging 1 in 75 for 6 miles. Similarly, in traversing many of the wilder parts of the Principality, the beauties of which have been opened up by this line, heavy expensive work was encountered. At Festiniog a tunnel had to be driven for the whole distance of 3,726 yards through solid rock. In the vicinity of Penmaenmawr the engineers have been pitted against a still more implacable enemy—the Irish Sea. On one or two occasions the waves have got the upper hand and have made breaches in the line which skirts the shore. To reduce the destructiveness of the sea to the minimum, heavy defence works have had to be completed.

Seeing that the London and North Western Railway, by its acquisition of the Liverpool and Manchester Railway, compasses practically the entire history of the steam locomotive, it has played a very important part in the development of the railway engine. It was on the Liverpool and Manchester Railway that the railway locomotive was born, where it assumed its type and commercial characteristics, and where the lines indicative of high speed were first worked out. From the "Rocket" to the "Sir Gilbert Claughton," the latest type developed upon this system, or the ponderous "Mallet," is a far cry, but despite the vast strides which have been made during the interval, fundamentally the latter do not differ from the former; the basic principles are the same.

Thus the story of the London and North Western Railway is virtually the story of the locomotive. Volumes could be written upon the latter, and the various developments that have been made, either in the interests of increased speed, augmented

haulage power, improved efficiency, or enhanced economy. Many names, inseparable from the evolution of the locomotive—Trevithick, Allan, Bury, Ramsbottom, Webb, Whale, Cooke—are associated with the London and North Western Railway, and its engines of different epochs—milestones in the history of development. Since 1843, when the works were laid down at Crewe for the repair of engines and rolling stock, but which subsequently became the locomotive building-eradle of the system, over 5,000 engines have been built. As may be supposed, among these are several which stand out more prominently than their contemporaries, either because of some remarkable performance, or because they introduced some new feature which either succeeded or failed, or provoked a storm of profitable discussion.

In 1847 Trevithick designed the "Cornwall," having drivers 102 inches in diameter, and with the boiler under the driving axle. She was a failure, but when rebuilt by Ramsbottom in 1858 she retrieved her reputation. Before she was withdrawn from service in 1904 she had covered 919,526 miles. These huge single drivers put up some fine speed records, especially when the conditions were favourable. The four-wheeled coupled locomotive with large drivers was a logical development in order to secure increased adhesion, and engines of this type acquitted themselves quite as famously. The "Hardwicke," with cylinders of 17 inches diameter and 24-inch stroke and drivers of 81 inches diameter, which in the famous race to Scotland during 1895 hauled the West Coast express from Crewe to Carlisle, put up a marvellous record. Notwithstanding the heavy pull over Shap Fell, with its rise of 1 in 75, the engine surmounted the bank, 6 miles in length, at a speed of 45 miles per hour, and put up an average of 67·2 miles per hour for the whole 141 miles. The "Charles Dickens" was another famous engine of this

L. & N.W.R. and Locomotive Development.

Some Celebrated Locomotives.

class, achieving notoriety for putting to her credit the greatest number of miles in regular express running by making the double journey between London and Manchester every day until 2,000,000 miles were recorded. Another doughty engine was the compound "Ionic," with two high-pressure cylinders of 15 inches diameter, and a low-pressure cylinder of 30 inches by a common stroke of 24 inches, and four coupled drivers of 85 inches diameter. On September 8th this engine hauled a train over the 299 miles between Euston and Carlisle without a stop, and thus created a world's record in non-stop performances.

The first engine which was built at Crewe for the express passenger traffic weighed about 20 tons, and hauled a load of some 40 tons at speeds ranging between 20 and 30 miles per hour. The latest express engines which have been turned out of the Crewe shops exceed 100 tons complete with tender, and are capable of hauling

loads weighing 400 tons at 60 miles an hour. The latest achievement of the London and North Western Railway is the "Sir Gilbert Claughton," which has been described in another chapter.

The railway has achieved a world-wide reputation for speed, comfort in travelling, luxury of its rolling stock, smoothness in running, and prompt service. These features are certain to attract traffic, and this fact is reflected by the annual transportation of over 80,000,000 passengers, the carriage of nearly 60,000,000 tons of merchandise, and the completion of approximately 50,000,000 train miles. This huge business serves to bring in a revenue of over £16,000,000 per annum, which is greater than that of any other British railway system, while its capital of £124,000,000 serves to justify the claim of the London and North Western Railway as being the "biggest joint stock corporation in the world."



By permission of the London and North Western Railway.

FRONT VIEWS OF THE "ROCKET" AND THE 5,000TH ENGINE
BUILT AT CREWE.



NEW CONCRETE SNOW-SHED, CASCADE SUMMIT.

The ferro-concrete sheds in course of construction. This photograph conveys a graphic idea of the steepness of the mountain sides.

Combating the Avalanche—II

THE NEWEST SNOW-SHEDS ARE BUILT IN FERRO-CONCRETE



THERE is another dangerous aspect which the engineer dreads. An avalanche, starting its travel from a point high up on a steep mountain side and travelling with fearful speed, may sweep over the shed, without inflicting any damage. It hits the bottom of the depression, but the momentum it has attained is so great that it rushes like a wave of water for 100 or 200 feet up the opposite mountain wall. When its velocity is expended it drops

back, and woe betide the line if it receives this backwash, as it were, for it will be battered to fragments. In some instances the snow-sheds even have been damaged and destroyed, not by avalanches which have rolled down from the crags and pinnacles immediately above them, but from slides which have descended the opposing mountain wall, have rushed across the depression, and have climbed the precipice on which the metals are laid, striking the snow-sheds from below, lifting them up, or breaking in the side and smothering the track.

While huge tree trunks and jagged masses of rock, weighing ten tons or more, are able to knock any human handiwork to smithereens, the "cyclonic wind" which accompanies the avalanche is equally destructive. The snow-fighters call it the "flurry," but they fear it as much as the snow-slide itself. The faster the latter moves, the more terrifying the local hurricane set up. It not only follows immediately behind the moving mass, but extends to a distance of 100 feet or more on either side of the avalanche's path, and is a whirlwind of fine particles of snow and other material which it picks up in its mad career. Often the flurry rises to a height of 100 feet. If the avalanche should be pulled up by some natural obstacle, such as the toe of the opposing mountain wall, the flurry rushes on ahead, following the line the slide would have taken had its movement continued. It tears branches away, up-roots the smaller jack-pines, snaps off the tops of the bigger trees, and, bearing the wreckage onwards, finally flings it out on all sides. I have been told that on one occasion a luckless railwayman happened to be caught by the flurry, although he was some distance away from the actual avalanche itself. He was picked up, spun round like a top, at the same time being lifted into the air and carried forward. When the wind had completed its frolic it dropped him, an inert mass, to the ground. His colleagues rushed to pick him up. He was limp and dead, although no injuries

were apparent. Not a thread was torn out of his clothes; no sign of a scratch on his skin, nor even a bruise was distinguishable. Yet when he was examined by the doctors there was not a bone in his body which was not either broken or dislocated.

The Canadian Pacific, however, is but one of the many railways crossing the North American continent which suffers from the devastation wrought by the snow-slide. In the United States the Great Northern Railway experiences almost as anxious and harassing a time during the winter season, especially where it sails the western slopes of the Cascades by daring loops. The mountain side, scarred by the galleries required to carry the tracks, are



THE NEW CONCRETE SNOW-SHEDS, CASCADE SUMMIT.
The reinforcing steel for the posts on the lower side of the line.

exceptionally steep, and the avalanches have magnificent uninterrupted runs. Their paths have been studied intimately, and at all points where such movements either occur regularly or are likely to happen massive timber sheds have been thrown up. As a matter of fact the line runs through long lengths of wooden tunnelling, which present a quaint appearance when viewed from the bottom of the valleys, resembling nothing so much as huge swallows' nests perched high on the cliffs.

So thoroughly was the snow-shedding protection carried out on this length of line, that the engineers were almost convinced that it was impossible for a slide to catch the road. But engineering optimism and confidence received a rude awakening. The Great Northern Railway was swept by a slide which excelled anything which it had encountered previously, and which precipitated the biggest disaster ever recorded in connection with snow.

The winter of 1909-10 was one of the worst experienced in the history of this great undertaking. February and March brought a snowfall almost unparalleled, and the blocks not only were numerous, but of unprecedented frequency and duration. This particular line appeared to be in the heart of the snow zone of that winter; at all events it suffered more seriously than its contemporaries. The snow-ploughs were out from morning to night, and the gangs fought valiantly, but to no apparent avail. A west-bound passenger train crawled into the tunnel which burrows under the crest of the Cascades for some three miles, and reached the western portal. There it had to stop. The Fast Mail was in a similar plight. Its flight was arrested by the self-same disturbing influence.

The avalanches roared down the mountains continuously. It seemed as if the gulch would be filled with debris brought down from above. The passenger train halted within the portal of the bore and

stood there, with its electric locomotives, for several hours. Then the passengers got fidgety. They dreaded an avalanche sweeping down and blocking their exit entirely. They approached the officials and begged that the train should pull out of the tunnel and down the line for half-a-mile to the town of Wellington, where they could stretch their legs. The train could not get through to the coast, as the line was blocked, although the snow-ploughs were toiling mighty hard in the endeavour to open the track.

The officials consented, and the train drew ahead to a point where the officials thought there was little danger of a slide descending upon the line. Here the train stood ready to advance the moment the line was open, the passengers living and sleeping in the Pullmans. A few intrepid travellers, either fretting at the delay or having a premonition of disaster, packed their traps and decided to push afoot to Seattle. They wended their way carefully down the rugged white mountain side, struggling over snow 20 and 30 feet deep, to Scenic, then tramped along the grade for 12 miles to Skykomish, whence they took train over the open line to Seattle.

The stalled train waited all day at Wellington, and the weary passengers at last turned into their berths. In the blackness of the night the snow started to move on the summits above, gathered impetus and weight, and tore down the mountain side, devastating the slopes over a width of half-a-mile of timber, loose rock, gravel and boulders. It struck the line where the passenger and Fast Mail trains were standing, picked them up and rolled them over and over a further 300 feet, leaving them in the mountain hollow buried beneath 50 feet of debris. Four electric locomotives also were caught in the slide's embrace and were thrown pell-mell into the ravine. Several passengers had miraculous

A Record Snow-slide.

The Wellington Disaster.

escapes, but a round hundred went to their doom.

No other catastrophe from snow can equal that of the American Great Northern Railroad. Its swiftness and magnitude staggered everyone. A fortnight elapsed before the lines were opened to permit trains to approach the point, although rescue parties toiled over the snow-garbed flanks in the effort to extend succour.

Among the first to reach the fatal spot were Mr. James J. Hill, the chairman of the railway, his son, the president, and Mr. Hogeland, the chief engineer of the system. When they arrived the rescue forces were digging through the ice, rock, and tree trunks, striving to reach the mangled passengers in the splintered and pulverised coaches.

The officials tramped the track for miles and scoured the mountain sides above.

"Whatever the cost the track must be protected against a repetition of this disaster. If it means millions it must be done," declared the chairman emphatically. "Start at once!"

The chief engineer completed his reconnaissance, and then returned east, preparing, during his journey,

Ferro-Concrete Sheds. his designs for snow-sheds

which would defy the avalanche. In order to secure impregnability during the ensuing winter, delays were dangerous, so by the time the chief had regained his office he had matured his plans, and was ready to put the constructional forces to work.

He decided to introduce a new type of snow-shed. Over half-a-mile of line, in a continuous length, demanded protection, and timber was out of the question owing to the fire danger. As an alternative the engineer decided to adopt ferro-concrete.

The rescuers had barely dug down to the wrecked train before large gangs of men appeared upon the track above, commencing operations for the erection of the huge structure which was to enclose the

double track in a concrete tunnel. A matter of 3,300 feet of line was to be treated in this manner. All traffic was diverted over side tracks, so as to permit the workmen to continue their labours in gangs, day and night, without interruption.

A somewhat strange spectacle was presented when I visited the spot. The sleepy mountain town of Wellington—little more than a hamlet—was alive and bustling. The railway builders were setting the iron frames forming the metallic skeleton, the mixers were toiling incessantly preparing the gravel and cement, and the concrete as rapidly as it was mixed was dumped into the moulds, so that the structure was assuming its form with amazing speed. Down in the valley, where a few dirty patches of snow still lingered, were fragments and splinters of the train which had been hurled to destruction, while the mountain side was scarred with a wide swathe showing where the avalanche had mowed its way.

On the mountain side of the track the rock and loose earth were removed to permit of the erection of a huge monolithic bank of cement, armoured and re-

How the Sheds were Built.

inforced with steel rods. On the opposite side, from concrete pedestals sunk into the ground, rose ribs of the same metal, a rod from each corner, and laced together about 12 inches apart. These were encased in wooden boxes into which the concrete was dumped and rammed tightly down, so as to form a homogeneous post of steel, cement and gravel. The tops of the posts were connected and interlaced with the steelwork forming the roof, which on the mountain side was anchored to the massive concrete wall. The latter is some 50 feet in thickness, and, being attached to the rock, forms practically part and parcel of the mountain. The roof of concrete, 10 inches in thickness, and sloping towards the canyon at one foot in five, is 22 feet above the rail level and covers both tracks.

The reinforced posts are set 10 feet apart in the six-foot way, while others are anchored to the rear wall for additional strength.

By the time the work was completed some 30,000 barrels of cement and 2,400 tons of steel had been worked into the 3,300 feet of shedding, and £100,000 had been expended. An outlay of £30 a foot to protect the track against the ravages of the snow-slide conveys some idea of the lengths to which American railways will go in order to ensure safety to their patrons. The Great Northern Railway is proud of this length of snow-shedding, which the engineers maintain, rightly, offers as complete a protection against the forces of the snow-slide as human ingenuity at present can contrive. Confidence in the protective measures has been supported adequately by experience, inasmuch as the sheds have been subjected to terrifying bombardments,

and have passed through the ordeals unseathed.

This innovation having proved so successful, other railways have adopted the ferro-concrete snow-shed principle. The Canadian Pacific Railway, after investigating the ferro-concrete structure, decided to introduce the principle upon their system in the Selkirks. The cost, however, would have been so prodigious that the possibility of avoiding the avalanche in its entirety was discussed and compared with the snow-shed method. As a result of these deliberations it was found that tunnelling through the Selkirks would not be appreciably more expensive, while greater security would be assured. Accordingly the Canadian Transcontinental Railway decided to drive the tunnel, which when completed will relieve the company of one of its most harassing and expensive anxieties.



THE WELLINGTON AVALANCHE DISASTER ON THE GREAT NORTHERN RAILWAY, U.S.A.

The largest single fragment of a car that was found.

Flashlight Signalling

A SYSTEM IN PRACTICE IN SWEDEN WHEREBY SPECIAL SIGNALS ARE UNMISTAKABLY IDENTIFIED BY ENGINE-DRIVERS



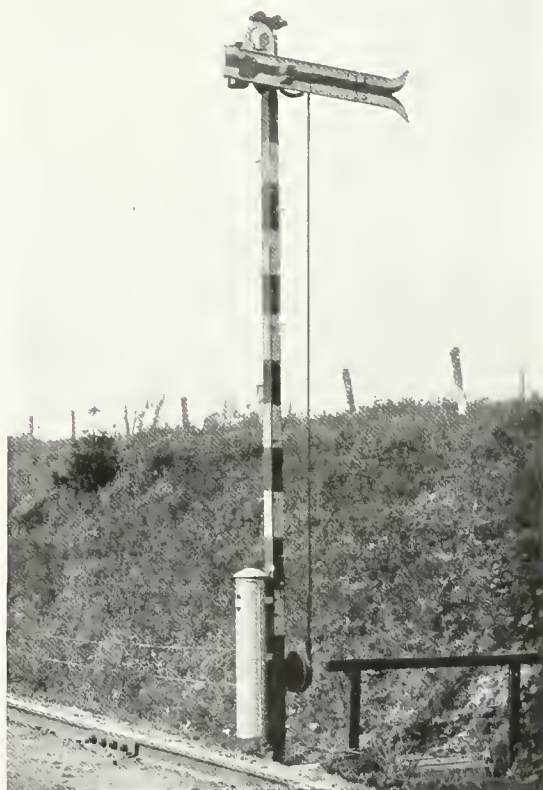
ALTHOUGH the British railway signalling system is conceded to be as near perfection as is humanly possible, and certainly is superior to that found in any other part of the world, whether considered from the points of efficiency, simplicity, or reliability, it is admitted that modern railway conditions demand improvements to safeguard high speed travelling at night. Railway signalling engineers admit this necessity, but the searching question is as to how it can be consummated to the best advantage.

In the British night-signalling system the driver is dependent upon the character of one of two lights. Red denotes "danger"; green indicates "line clear." In some countries a third light, violet, is introduced to convey a different intimation, while in other instances the "line clear" is shown by a white light. The latter labours under one serious objection. A white light may be shown when the red disc of the spectacle glass is broken. In that event, the driver would be correct in surmising that everything was all right, and if an accident ensued he could not be blamed. Upon the British railways if a driver saw a white light shown by a signal, he would pull up, whether the line was clear or otherwise, as he would know that something was amiss with the signal. Another disadvantage of the white light is that in busy centres it is apt to be confused with lights which have nothing to do with the railway.

But when one recalls the vast array of signals which are displayed to guard busy junctions, one will realise that the selec-

tion of his particular signal light is by no means an easy task for the driver. The issue becomes complicated when running round a curve, since as the junction is approached the signal lights may change their relative positions. For instance, a signal which the driver picks out as his own may be seen to the extreme right of the others when entering the curve, but when the latter has been rounded it may have shifted its position to the extreme left.

Again, one must remember that on the



A DISTANT SIGNAL ON THE DANISH STATE RAILWAY, FITTED WITH THE AGA FLASHING LIGHT.

British railways every mile of line is guarded. The driver of a London and North-Western express has to pick up about 300 signals in the 158 miles between

each, it is quite possible that he may lose his bearings, especially if the weather be at all misty.

"Watching for signals" constitutes the most trying part of the driver's duty, and, what is more to the point, he has got to interpret each signal as it looms up. Anyone who has travelled on the footplate of an express at night, and has experienced varying descriptions of weather, will admit that the situation of the driver is by no means enviable. Even the finest, longest, and quickest sight is tested to a supreme degree in picking up and in interpreting correctly a signal during a blinding hail or rain storm, while the layers of mist, hanging at varying heights, are apt to obscure a signal so completely that the train is upon it before it is seen.

From the express driver's point of view his labours are enhanced very appreciably by the lack of distinction between the distant and home signals. Both show the same light characteristic, although they convey totally different instructions. Of the two, the distant is the most important, as it indicates the probable position of the home signal, and, if adverse, warns the driver to ease up, although by the time the home signal comes into view the line may be shown as clear.

Although many people regard a driver in the light of a highly developed sensitive governor, as it were, of the machine under his

hands, he is human after all, and, consequently, is liable to err. The most expert driver will admit that at times he loses his bearings, and, although he is quick in picking up his whereabouts, much can happen in the short period of distraction. Accidents have probably occurred purely because the driver has passed his distant



A THREE-ARMED HOME SIGNAL ON THE BERGSLAGENS RAILWAY.

This railway has more than 100 flashlight signals. The top lamp is provided with flashlight, the lower lamps have steady lights (acetylene).

London and Crewe, and, seeing that at times he may be travelling at sixty or more miles per hour, the strain upon the eyes and nervous system is necessarily severe. So long as attention can be concentrated upon the road a mistake is improbable, but should the driver be forced to turn his eyes from the track to the mechanism in his

signal unconsciously, or has mistaken the home for the distant signal, while the instances where disaster has been averted



NEW TYPE ACCUMULATOR-BOX OF THE AGA FLASHLIGHT—SHUT.

narrowly because the driver has discovered his mistake in the nick of time are legion. Fortunately, the majority of drivers do not depend upon the eye alone, but are able to divine their situation with tolerable accuracy from the noise of the train, especially if they are thoroughly familiar with the road. Indeed, the sensitiveness of the ear in the expert driver is as remarkable as the quickness of his sight.

After all is said and done, however, it is obvious, seeing that so much depends upon the detection and interpretation of the distant signal, that it should be given a distinctive characteristic. On some systems an effort to this end is made by giving the light a violet tint, but the objection to this procedure is that this colour possesses a very indifferent penetrating capacity. It cannot be detected from such a distance as red or green.

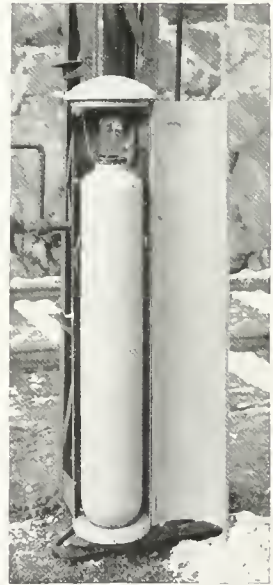
How can the distant signal be given a distinctive characteristic, and one which will catch the driver's eye as easily, if not more readily than that in vogue? This question arose upon one of the private railways of Sweden, and the authorities embarked upon a series of experiments in this direction. A variety of suggestions were advanced and investigated minutely, but were abandoned as impracticable for various technical reasons. Then one of the engineers, conversant with the fact

that flashing lights are used at sea, and are highly appreciated by mariners owing to the facility with which they can be picked up and interpreted, suggested that trials should be made therewith.

It was not an experiment in the usually accepted sense of the word, because the marine flashlight had been reduced to a scientifically correct and practically commercial basis. Dr. Dalen, the eminent Swedish scientist, whose researches upon light phenomena are so famous, had solved the question very completely for marine purposes. Accordingly, the railway requested the organisation exploiting Dr. Dalen's inventions, the Gas Accumulator Company, Limited, of Stockholm, to apply the idea to railways, if at all feasible. Seeing that this was the first occasion on which the company had been asked to adapt flashlight signalling to railways, and realising that the conditions between land and sea travelling were so different, an interesting series of tests were undertaken

with a view to evolving the system of flashing best suited to railway working. Finally, it was found that, from the optical point of view, little modification was required: the question became resolved into the adaptation of the idea to railway operation, but as this was a mechanical issue no difficulties were anticipated, and, in fact, were not encountered.

The Swedish railway signalling engineers who had suggested the development were strengthened in their opinion that a flashing system of signalling would be more



NEW TYPE ACCUMULATOR-BOX OF THE AGA FLASHLIGHT—OPEN.

effective from the fact that the human eye is more sensitive to intermittent interruptions of a ray of light than to a steady gleam. In other words, a light which is caused to flash at regular and at comparatively short intervals will be detected more easily and from a greater distance than the steadily burning light. The value of the flashing light as a means of arresting attention is demonstrated every night in the busy thoroughfares of our big cities, where flashing advertisements have displaced steadily illuminated signs, merely because they catch the eye. Even if a flashing sign is surrounded by a number of constantly illuminated advertisements, no matter how brilliant the latter may be, the former with its alternating dark and light periods will strike the eye, while the others may be passed unnoticed. This is because the eye notices the flashing sign involuntarily.

When the first flashlight signal was applied to a railway, similar results were observed. The driver of a train detected the flashing signal, and realised its significance long before he recognised the stationary lights. Also he found it easier to individualise it from a bewildering array of warnings, and, what was more to the point, he was able to notice the light without particularly looking for it. Moreover, knowing that the flashlight mounted upon the distant signal guarded his train, he sought for that only. If he failed to find it, he became uneasy and at once slowed down his train until the home signal was picked up, and his confidence was restored.

A driver who is protected by flashlight signals suffers less physical and nervous racking. He has one character of light only to pick up, and he looks for it, ignoring all other lights which may be in the vicinity. His signal may be placed upon a gantry where perhaps fifty green and red steady lights are gleaming, but instantly he singles out the flashing light.

As the mariner, when feeling his way along a coast, is able to select his flashing light from the host of other land and ship lights, so is the railway driver able to find out his particular beacon. Even in misty and blustery weather, when a steady light can be picked up only with extreme difficulty, the flashing light is detected with extreme ease and from a longer distance. The possibility of confusion is eliminated entirely, while there is neither hesitancy nor doubt.

The preliminary tests on the private railways of Sweden having established the unquestioned value of the flashing light, the development underwent extensive application. It received a decided stimulus by the accident which happened at Kåbs Station on the Bergslagens Railway, owing to a driver misinterpreting a signal. The flashing light was installed to prevent a repetition of the disaster, and since this installation has been in service the drivers running through this junction have confessed that their labours have been eased very appreciably, and that they can approach the junction, even at highest speeds, with less doubt and hesitancy than was the case under the previous fixed light method.

In Sweden the flashing system is displacing the older method very rapidly, both upon the private and Government lines. The drivers of the expresses have urged the necessity of a distinctive class of signal for their particular work, and have stated emphatically that, in the protection of a high-speed train, the flashing signal is the most effective which has been evolved yet.

It is obvious that the flashlight system cannot be applied to all existing signals. It must be used in conjunction with the ordinary type of fixed light. If all signals were converted to flashing the plight of the driver would be worse than it is now. There would be as little, or even less, distinction between various signals; in fact,

Adoption in Sweden.

The Insistent Flashlight.

the driver would be harassed more than ever.

The advocates of the system maintain that it should be used for special work, such as the guarding of the fastest expresses. It might be applied to distant signals, so as to distinguish them completely from the home signals: or, on the other hand, the steady light might be retained for the distant signal, and the flashlight restricted to the home and through station signals. In the latter event the driver, even if he over-ran the distant signal, would pick up the flashing home signal, and from a more distant point, so that he would be in a position to act more quickly, if the necessity arose, and with less risk of accident. Moreover, there would be another advantage in this application. In running through a busy junction, guarded possibly by forty lights, the driver would search only for the flashing lights. They would be installed for the protection of his road only, and therefore the task of watching for signals would be reduced very appreciably.

If used in this connection, running through the busiest and largest junctions would be facilitated, even if the main lines branched off into half-a-dozen different express tracks. Each road probably would have only two express tracks—one up and one down—so that only twelve lights would have to be installed—six facing either direction. Therefore the driver would only have to single out his particular flashing light from among six, instead of, as at present, detecting his particular green signal from forty or more fixed lights, many of which may be showing “line clear” intimation for different roads at one and the same time.

The “Aga” system, as that invented by Dr. Dalen is called, is absolutely automatic in its action, and is used in conjunction with acetylene gas. It is cheap, while a single charge is adequate for two months’ working without attention. The light burns both night and day, so that

the signal is always lighted—a distinctive advantage in countries susceptible to fog visitations. The essential feature is the flasher, whereby the distinctive light characteristic is obtained. It comprises a small



PUTTING IN A FILLED ACCUMULATOR (OLD TYPE OF BOX).

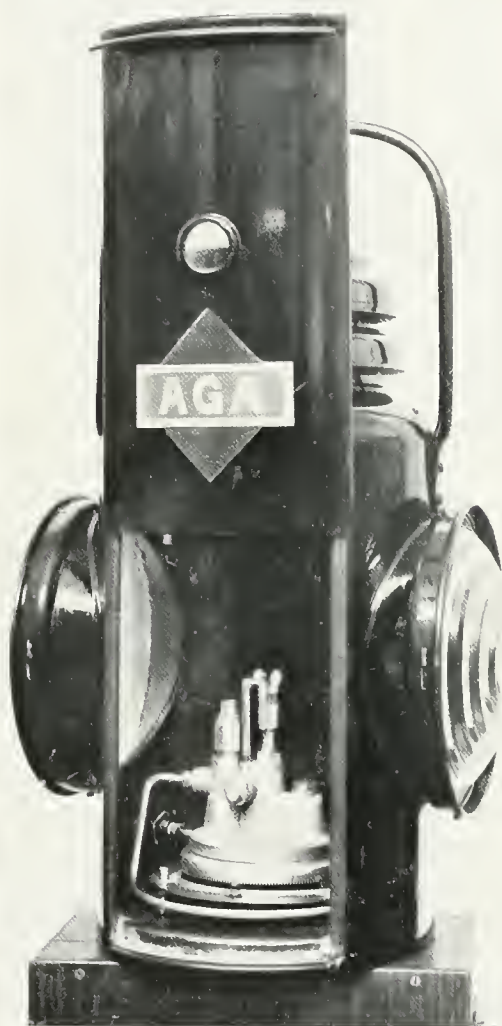
reservoir, into which the gas flows from the accumulator, fitted with a burner. When this reservoir is charged a valve is opened by the gas pressure, and the charge of gas escapes to the burner, where it is ignited by the pilot flame. This flasher has been in use in connection with lighthouses, lightships, and buoys for many years past, so that its practicability, efficiency, and reliability are assured. The apparatus can be adapted to produce as many flashes per second as may be required. The complete installa-

tion for every signal is of a very simple character, and in the majority of cases can be fitted to the existing type of lamp. The acetylene gas in the dissolved form

its working period, may be varied according to the situation of the signal, but in the majority of cases an accumulator sufficient for two months' service is used.

Owing to the simple design of the flasher, the few integral parts, and their strong construction, the danger of breakdown is eliminated, while the possibility of the signal failing to act is inconceivable. Once the accumulator is coupled up to the flasher, and the pilot flame is lighted, the apparatus continues its work regularly until the supply of acetylene is exhausted. The reliability of the invention may be realised when it is stated that some of the first flashers installed upon the Swedish railways have produced over 100,000,000 flashes and have never once failed or shown the slightest sign of irregularity in working. Bearing in mind the rigorous character of the Swedish climate, with its extreme fluctuations in temperature, and the severity of the winter, blizzards and rain-storms, it will be admitted that the apparatus has been submitted to as severe a test as could be conceived. Completely satisfactory working under these conditions should be sufficient to prove that the apparatus is adaptable to any railway on the globe.

At first sight it might be thought, as the light flashes both day and night, that it may be somewhat costly to run. This is a fallacious impression. The average cost comes out at about 100,000 flashes, or 70 hours, for one penny. This is far cheaper than any other system in vogue, and its economy is augmented by the fact that the item of wages is reduced, because the lamp only requires attention once in two months or so to renew the accumulator charge. All that is necessary is to disconnect and withdraw the empty reservoir, and to introduce and connect up the charged vessel, examine the burner, and light the pilot flame. The whole operation can be completed in a few minutes, and the signal can then be left safely for



THE AGA SEMAPHORE LAMP WITH FLASHER MOUNTED.

is stored in a small portable accumulator, resembling the cylinder in which oxygen and other gases are compressed, placed in a small box at the base of the signal post, and connected to the lamp through a supply pipe. Being in the dissolved form the acetylene is perfectly safe to handle, while there is no danger of explosion whatever. The size of the accumulator, its capacity, and, consequently,

another two months. Under the present system a man is required to light and extinguish the lamps at dusk and dawn respectively, and this duty represents an appreciable item in the wages bill. Upon foreign and colonial railways, where the labour problem is somewhat acute, the flashing system, apart from its other advantages, offers a complete solution of a very difficult question.

When the system was first taken up in Sweden, the question of the duration of the light and dark periods and the number of flashes per minute demanded solution, so as to secure the most perfect results from the driver's point of view. An elaborate series of tests were carried out to this end, and a mass of interesting data was collected. When this detail was resolved the following points were established:—

(1) That a comparatively short light period gives the most characteristic signal. (2) That the dark period should not exceed 0.9 or one second, because the driver is apt to lose his bearings, develop feelings of uneasiness, or be mistaken if the period of darkness is longer. (3) That the duration of the light period, within certain limits, is of secondary importance, a flash of 0.1 second duration scarcely being distinguishable from one twice the length. (4) That about 60 flashes per minute form a first-class all-round standard. If the number is increased, say, to 120 flashes per minute an extremely nervous effect is produced upon the driver, while if fewer than forty flashes in the same interval are given the driver becomes uneasy. But in very high speed express work it was found that the number of flashes might be raised to seventy or eighty per minute with advantage. (5) That a long light and a short dark period does not give a satisfactory characteristic signal. (6) That two flashing signals must not be placed too closely together. A stationary light must be placed between the two to eliminate all feelings of uncertainty and confusion. This defect

becomes particularly noticeable if the two flashing lights are mounted upon one post. Yet the disadvantage may be eliminated if the two signals are given divergent flash characters, that is to say, different proportions between the light and the dark periods, making one to give, say, fifty, and the other ninety, flashes per minute. Then no difficulty is experienced in reading the signal correctly, owing to the wide variation in the character of the flashes.



THE AGA FLASHING APPARATUS FOR RAILWAY SIGNALS.

But the number of flashes per minute must depend to a great extent upon the local conditions and the character of the traffic to be protected by the signals. The driver must receive a sufficient number of impressions between the moment he first sights the light, and when he is at a point affording him ample space in which to pull up easily before reaching the signal. When a train is travelling at sixty miles an hour from three to five flashes are necessary to convince him on this point, and at sixty flashes a minute the train will have travelled from 264 to 440 feet during this period. If the flash is very short, experience has proved that a somewhat greater number of flashes are requisite to convey an unmistakable impression. In Sweden, where the flashlight has been

applied to distant signals, the flash character is 0.1 second light followed by 0.9 second darkness, which is equal to sixty flashes per minute.

At the Liljeholmen station on the southern main line of the Swedish State Railways, where the Aga flashlight system has been introduced on the home signals, several different flash characters have been employed in order to determine whether the flashes of relatively long light periods are effectively distinguishable from the short flashes of the distant signals, and also to ascertain which of the four flash characters is the most suitable. The flash characters under test are respectively as follows :—

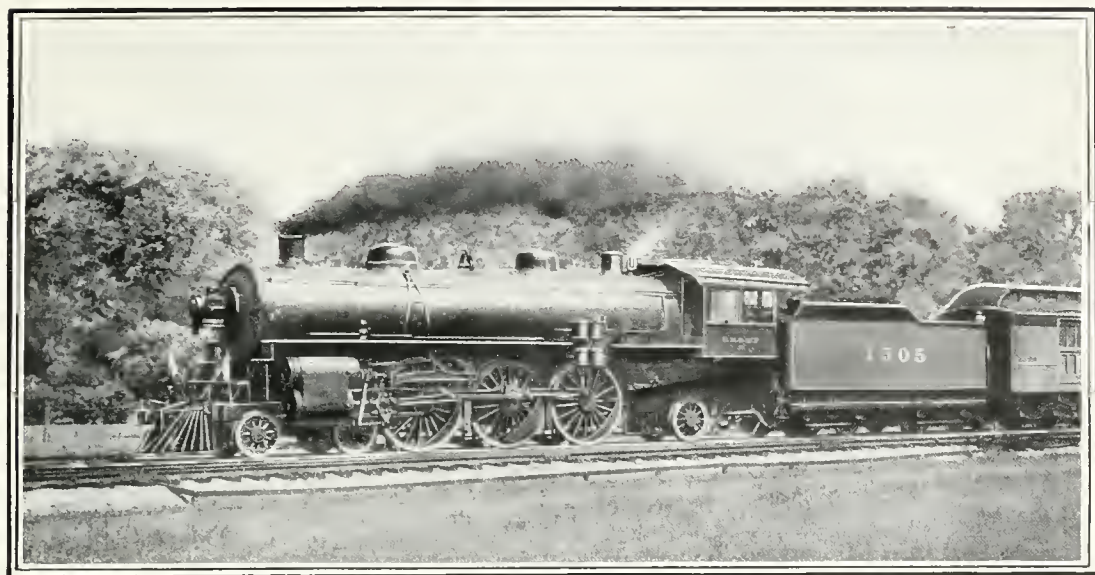
<i>Seconds Light</i>		<i>Seconds Dark</i>		<i>Flashes per minute</i>
0.4	followed by	0.8	50
0.5	0.8	46
0.5	0.7	50
0.5	0.5	60

Since the system was introduced experimentally upon the private Swedish railways it has made great strides. The State railways have embraced the idea, being convinced of its value, and it will not be long before the whole of the lines are guarded in this manner. In Denmark, Russia, and Holland the invention is regarded favourably. While certain of these installations are purely of an experimental type, the results so far have been so satisfactory that little doubt is entertained that they will be adopted. So far as Great Britain is concerned, our railways are watching the development of the idea very closely, the fact that it might be adapted to certain phases of express main-line operation being conceded. In the United States and

Canada a similar attitude is being manifested. In these latter cases a comprehensive signalling system throughout the two countries is in process of fulfilment, the railways spending huge sums to bring their roads into line with European practice. Seeing that the Aga flashlight system is absolutely automatic in its action, is very economical both to instal and maintain, requires the minimum of attention, in addition to giving a very convincing and distinctive warning, it undoubtedly constitutes an ideal signalling system for new countries. Moreover, the complete success of the idea in its application to marine lighting is a powerful recommendation in its favour.



A DISTANT SIGNAL ON A SWEDISH RAILWAY
FITTED WITH THE 'AGA' FLASHLIGHT.



A CHARACTERISTIC "PACIFIC" (4-6-2) TYPE OF LOCOMOTIVE.

An Experimental Locomotive

IN BUILDING THEIR 50,000TH ENGINE THE AMERICAN LOCOMOTIVE COMPANY EVOLVED AN INTERESTING DESIGN OF THE "PACIFIC" TYPE



THE builder of the locomotive, in meeting the requirements of a railway, is compelled to submit to the rigid specifications laid down by his client. The result is that the engine is not always so efficient as it might be, as the personal question, as represented by the engineer or manager of the railway, enters into the issue. To prove this point, and just to ascertain what could be done if the firm's engineers were given a free hand, the American Locomotive Company, which is an amalgamation of a number of locomotive builders, decided, on the occasion of the construction of its 50,000th engine, to carry out the work upon its own initiative. The engine was admitted to be an experimental engine, designed and constructed at the company's

own expense. Accordingly, being untrammelled by any particular specifications, or the necessity to conform to the existing standards of any railway company, the builders were free to embody in this particular locomotive their ideas concerning the best locomotive engineering practice.

In the execution of this interesting experiment the company did not attempt to evolve anything freakish or unusual. They simply took an existing type of engine and improved it in accordance with their accumulated experience, which is considerable and varied, owing to the diverse and peculiar character of their constructional operations. The type selected was that known as the Pacific—4-6-2—which has become recognised in America as the most efficient standard for all-round express passenger service.

The Pacific class is a logical development of the Atlantic 4-4-2 type, and has attained its present vogue because it has proved so completely successful for its particular work under all and varying conditions. In Great Britain there is only one expression of its design—the “Great Bear” of the Great Western Railway, and although this engine evidently is successful

maximum power per pound of weight, and they succeeded in a remarkable manner, seeing that under tests in actual service the engine has developed 2,216 horse-power, which represents one horse-power for every 121·4 pounds of total weight. Locomotive engineers who have seen the locomotive agree that it is a business-looking machine in every respect, and from a perusal of its



AN EXPERIMENTAL "PACIFIC"

The total weight of engine and tender is $215\frac{1}{4}$ (American) tons. The total

in operation, curiously enough it has not been taken up generally. On the continent, however, it is becoming more and more appreciated, and is being produced in increasing numbers, not only for the home systems, but also by the private builders for the various railways of the world.

Under these circumstances, therefore, the American Locomotive Company, by its selection, had a good opportunity to excel, especially in view of the acknowledged need of greater sustaining capacity to meet the requirements of modern passenger train working.

The builders set out to provide the

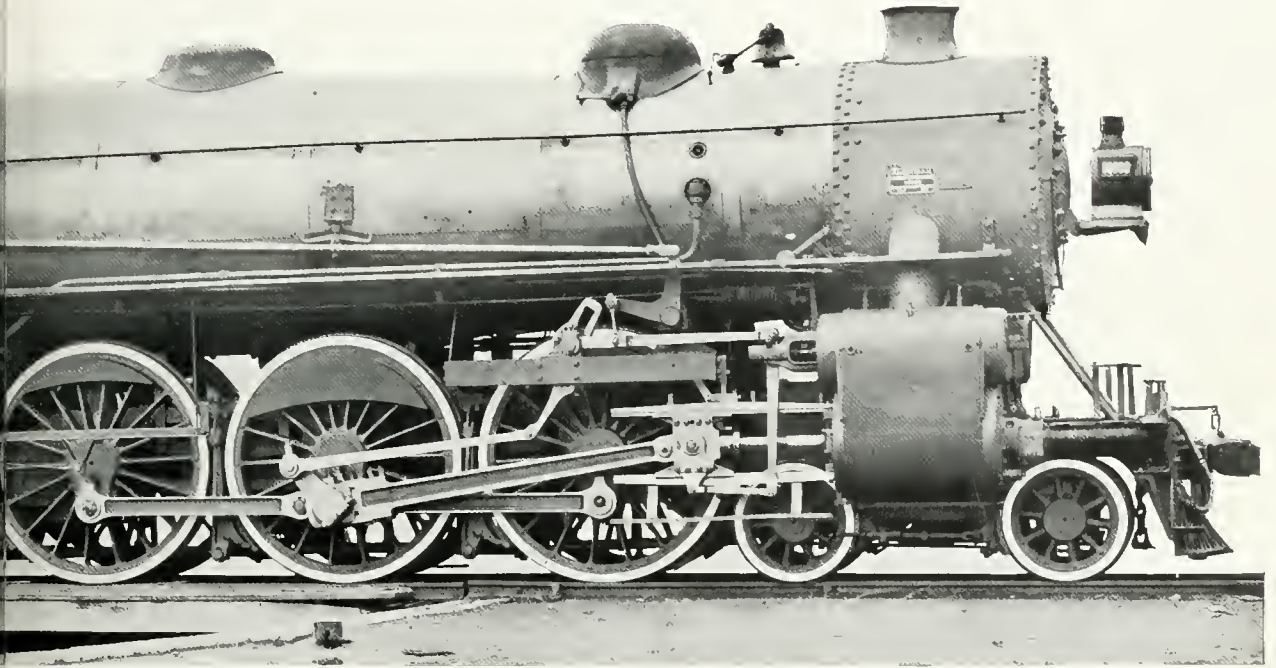
performances, or a more intimate acquaintance with it on the road, are prepared to admit that it is of an epoch-making character. From the operating point of view it has been equally impressive, inasmuch as the machine has shown a fuel economy exceeding 25 per cent. over engines of the same type and equal weight of conventional design.

The end which the bunders set out to attain has been achieved by the fullest application of the most approved developments in locomotive design and materials. The latest knowledge of general proportions, the most recent developments in materials, improvements in the design of

details the best use of accepted fuel-saving devices—all these factors were combined in this machine in order to secure the utmost possible economy in operation.

In order to accomplish the primary purpose of the design, the largest boiler capacity within the predetermined wheel loads was the essential feature. Every pound of weight that was not necessary to

The driving wheel base is 14 feet, that of the engine 35 feet 7 inches, and of the engine and tender 68 feet $2\frac{1}{2}$ inches. The weight of the engine is distributed as follows: Leading wheels, $24\frac{3}{4}$ tons; driving wheels, $86\frac{1}{4}$ tons; and $23\frac{1}{2}$ tons upon the trailing wheels. The total weight of the engine, therefore, works out at $134\frac{1}{2}$ (American) tons. The tender, of the



(4-6-2) TYPE OF LOCOMOTIVE.

heating surface 4,048 square feet, and of superheating surface 897 square feet.

secure strength or durability in the component parts was eliminated. The weight thus saved was utilised for the provision of a larger boiler, and the increase of the capacity of this boiler by the provision of fuel-saving devices, in order to obtain the greatest possible economy in boiler and cylinder performance.

The boiler has a diameter of $76\frac{3}{8}$ inches, and steam is used at a pressure of 185 pounds per square inch. The fire-box measures $114\frac{1}{8}$ inches in length by $75\frac{1}{4}$ inches wide. The tubes, 234 in number by 22 feet in length, comprise 207 of $2\frac{1}{4}$ inches and 36 of $5\frac{1}{2}$ inches diameter respectively.

8-wheeled type, has capacity for 8,000 gallons of water and 14 tons of soft coal. In running order it weighs $80\frac{3}{4}$ tons, bringing the aggregate weight of the machine, engine and tender, ready for the road, to $215\frac{1}{4}$ tons. The maximum tractive effort is 40,600 pounds.

The total heating surface of the locomotive is 4,048 square feet, the superheating surface 897 square feet, and the grate area 59.75 square feet. This is far in excess of any other superheated Pacific locomotive of equal weight. In superheating surface alone the area exceeds that provided in any other American passenger engine built up to the time of its appearance.

The cylinders, with a diameter of 27 inches by 28 inches stroke, are of vanadium cast steel, and weigh 2,600 pounds less than cast steel cylinders bushed with cast-iron of the same stroke, but only 22 inches in diameter, while as compared with cast iron cylinders of the same dimensions and type a saving of 4,000 pounds is obtained.

Several distinct innovations in regard to American locomotive practice have been introduced. The steam pipes connecting with the cylinders are placed outside, and although a radical departure it has been received favourably. The screw reverse gear, which has become adopted almost universally on British and European engines, was provided for the first time. This appropriation of an Old World idea was not regarded favourably at first in many quarters, inasmuch as the American locomotive engineer is wedded to the reverse lever, despite the fact that its handling is becoming increasingly difficult in large engines, and that it represents loss of economy and efficiency. But the driver, the man who has to handle the machine, and who has been brought into touch with the innovation upon this engine, has expressed his preference for the screw reverse, once he has become used to it, very unequivocally. The advocates of the reverse lever have maintained hitherto that it is easier and quicker to handle the lever than the screw-gear. This theory has been shattered as a result of practical experience.

Many other refinements to secure the

builders' ends were incorporated, and have tended to show that, although the United States engineers have made great strides in the development of the locomotive, the skill of the Old World is by no means exhausted in this particular field, and that true advance only can be made by the mutual exchange of ideas.

That the builders of No. 50,000 carried out their experiment upon the right lines is borne out by the fact that many of the improvements over long-accepted conventional practice in the design and construction of some of the principal details since have been adopted as standard features by themselves, practical experience having established their value. Moreover, these refinements have been applied widely to a large number of other locomotives since, with marked success from all points of view—from the general manager to the mechanical engineer and driver.

So far as American locomotive development is concerned this is the first instance on record where a private firm has built a locomotive upon its own initiative and at its own expense for the purpose of advancing locomotive design. The engine has been tested freely, and has given complete satisfaction to all who have handled and watched its performances. The engine is acknowledged to steam easier, and to impose less physical exertion upon the fireman in the maintenance of the steam pressure, than other Pacific engines of conventional design up to the appearance of No. 50,000.

**Improvements
Accepted.**



160-FOOT SINGLE-LEAF DOUBLE-TRACK SCHERZER ROLLING LIFT BRIDGE ACROSS THE CUYAHOGA RIVER AT CLEVELAND, OHIO, U.S.A., IN CLOSED POSITION.

This view shows the manner of mounting and operating it on a steel tower 70 feet high. This bridge has been duplicated by the Soudan Government for a crossing over the Nile.

The Rolling Lift Bridge

A FORM OF BASCULE BRIDGE, THE CHARACTERISTICS OF WHICH ARE SIMPLICITY OF WORKING AND INEXPENSIVENESS OF CONSTRUCTION



SPANNING a river is always a problem of considerable moment to the railway engineer; there are so many factors to be borne in mind. Not only is he forced to keep the essential and rigid requirements of the steel highway to the forefront, but he is compelled to fulfil the demands of other interests. The issue is aggravated in its complexity when the crossing is over a busy waterway, in a congested city or town, and when the banks are somewhat low-lying. The claims of navigation have to be regarded, often to the disadvantage of other methods of transportation.

In meeting such different conditions,

the engineer has displayed considerable ingenuity. Three methods of meeting the situation are available—tunnelling beneath the waterway, installing a train ferry, and bridging. The first is impracticable, except in rare circumstances, from motives of cost and the difficulty of flattening the approaches to the subterranean highway sufficiently to secure easy, economical movement. The second generally is not feasible, as it entails serious delays. Bridging, therefore, remains as the solitary expedient, and this is the solution invariably adopted.

Here again, however, difficulties arise. What is the type of bridge most suited to the prevailing conditions and able to meet to the best advantage the claims of both

railway and navigation? This is an issue which cannot be decided without the most minute investigation. The bridge may be built at a sufficient height above the waterway to afford adequate headroom to the traffic passing beneath, but in

Thames, which principle has come into somewhat extensive vogue during recent years.

The bascule bridge probably is one of the oldest bridge-forms known. In the Middle Ages, when castles and moats were



160-FOOT SINGLE-LEAF DOUBLE-TRACK SCHERZER ROLLING LIFT BRIDGE ACROSS THE CUYAHOGA RIVER AT CLEVELAND, OHIO, U.S.A.

This view shows the bridge open. The front part is 255 feet above the water.

this event the natural contour of the land must be propitious to the provision of the approaches, unless expenditure is a secondary consideration. If these favourable conditions do not prevail then the engineer must provide some means of interrupting the railway link when and as required in coincidence with marine requirements.

This end may be fulfilled in many ways. The engineer may introduce a vertical lift method as described on page 54; a swing bridge, the solution which has met with the widest approbation hitherto; or a bascule system similar to that adopted in connection with the Tower Bridge, across the

the fashion, it was known as the draw-bridge, but with the advent of modern civilisation it fell into desuetude. It was only when railway and navigation interests came into conflict that it underwent revival, and has received its most powerful illustration in modern times in the Tower Bridge.

About eight years after this monumental work had been commenced, an American engineer, William Scherzer, conceived a new type of bascule bridge, the salient features of which were greater simplicity, both of design and operation, extreme cheapness in installation, maintenance and

working, and enhanced speed in operation. The invention aroused instant attention, as its engineering features were too pronounced to be ignored. In some quarters the claims of the inventor were criticised, but the opportunity arose whereby he was able to demonstrate the practicality of his idea, and to establish his contentions in no uncertain manner. The Metropolitan West Side Elevated Railroad desired to get into the business centre of Chicago, but was faced by the Chicago River. The company wanted to lay down four roads, for which the right of way had been secured. This extended between two existing swing bridges, and although the railway company at first concluded that the swing bridge would meet their requirements, they found it impossible to adopt this solution, for the simple reason that there was no space in which to place the structure, as the existing bridges were too close together.

As a solution of the difficulty, an eminent American engineer suggested that a bridge, similar in character to the Tower Bridge and working upon the same principle, should be adopted. The authorities

**Triumph of
the Scherzer
Bridge.**

acceded to the proposal, and the plans were taken in hand. As the latter matured, however, certain drawbacks were observed. At last the railway management called in Mr. Scherzer to determine whether his new idea was applicable to the situation, and, if so, would it be suitable to the purposes demanded. Time was pressing, since the remainder of the track was almost completed. Mr. Scherzer had been turning over in his mind the possibility of evolving what he termed "a rolling lift system," and he saw that it could be incorporated in this case very efficiently, so he prepared plans in accordance with his ideas. The first designs were submitted to the management, and they were so impressed with its advantages that they placed the contract in his hands.

The bridge is, in reality, in two sections. Two duplicate structures, each carrying two sets of metals, are built side by side, and firmly coupled together so as to be operated as one bridge. Inasmuch as it might be desired to use each section separately, the designer introduced facilities whereby, within ten minutes, the coupling can be severed, and each bridge operated independently of the other, so that the railway has a crossing at all times. The movable span is 114 feet, centre to centre of bearings, and the channel between the masonry piers is 108 feet. This structure is designed to act upon either the arch or cantilever principle. When acting as a cantilever the live load is supported by the tail girders, which are locked under the projecting approach spans, the latter being firmly anchored into the masonry. The counterweighting is so carried out that upon opening the tail and centre locks, the leaf rises to an angle of about 30 degrees, so that only the minimum of energy is required to open it still wider or to close it. As a rule, the bridge can be opened or closed within thirty seconds, and is ready to permit trains to pass within a minute of its commencing to close.

This particular bridge constituted a severe test for the new idea, inasmuch as the Chicago waterway is very busy, while the railway traffic is heavy. On the average, 1,200 trains cross the bridge during the twenty-four hours, while the bridge itself has to be opened about forty times a day to permit vessels to pass. Rapid working in this instance was of paramount importance, so that the railway traffic might not be hindered more than was absolutely necessary. Experience has demonstrated very conclusively the many advantages of this type of bridge. In fact, the railway company were so impressed with its superior features that immediately afterwards they approached

**1,200 Trains
Per Day.**

the civic authorities and received the requisite permission to convert the adjacent swing bridge to the Scherzer Rolling System.

Another illustration of the possibilities of the system was furnished also in the same city, and this example served to show how economically such a structure can be built and operated. The Chicago Terminal Transfer Railroad Company selected the system in order to provide them with access to the Grand Central station. The design called for a clear opening of 255 feet between the piers—55 feet more than the opening of the Tower Bridge. In the latter structure the total weight of iron and steel is about 14,000 tons; it has a capacity of some 5,000 pounds per lineal foot of bridge; the total moving load on the shafts of the pivot whereon the leaves move is 2,400 tons; while two hydraulic engines, each of 360 horsepower, are required for operation. In this particular Scherzer bridge the total weight of the metallic parts is only 2,250 tons; it has a capacity of 10,000 pounds of moving load per foot of bridge—twice that of the Tower Bridge. The total moving load is only 1,773 tons; while two 50 horsepower electric motors suffice to operate it. This Chicago bridge was erected complete for £25,200—less than the expenditure involved in connection with the hydraulic machinery alone of the Tower Bridge. This Scherzer bridge has the longest movable span yet provided upon this system. The leaf is 275 feet in length, and has to be opened occasionally as many as 100 times a day.

Needless to say, this very marked difference served to emphasise the possibilities and economy of the Scherzer Rolling System in no uncertain manner. Therefore it is not surprising that engineers recognised that in this invention they were offered a complete solution of the difficulties which harass them under such

conditions from time to time. The various railways running into Chicago which were forced to cross the navigable waterways embraced the idea; while the civic authorities, on their part, recommended the bascule bridge because it rendered a wider navigable channel available to the busy maritime traffic.

It may be pointed out that the Scherzer is by no means the only expression of the bascule bridge of to-day, but it was the first to be operated upon the rolling lift principle. The idea is very simple. If one takes a wheel and divides it into four equal parts, and then sets up one of these segments vertically upon a horizontal runway, forming a track as it were, and upon the upper side lays a plank horizontally, so as to overhang in the form of a leaf, one has the Scherzer bridge in its most primitive form. Now if one presses down the tail end of the leaf the segment will run backwards in the manner of a quadrant, causing the leaf to swing up through the air until it is vertical, the tail end then resting upon the ground or dipping into a pit. Such is the basic principle of the Scherzer bridge and its operation, and it is the simplest form of bascule which has been designed yet. In fact, extreme simplicity was the point for which the inventor strove, and in this quest he succeeded completely. Of course, in perfecting the idea from the foregoing nucleus, other mechanical details were taken into consideration, so that the essential movements might be made with the minimum of friction.

The idea can be adapted to meet any requirement. It can be worked upon the double-leaf principle, similar to the Tower Bridge, in the case of wide waterways such as a river, or when spanning a canal a single leaf can be used. In any event, the full width of the waterway can be left free for boat traffic. The bridge can be made

**Another
Chicago
Bridge.**

**Principle of
the System.**

**Elasticity
of the Idea.**



TWO SINGLE-LEAF SCHERZER ROLLING LIFT BRIDGES, MOUNTED SIDE BY SIDE, OPERATED FROM OPPOSITE BANKS.

Each bridge carries two sets of metals. This photograph shows the rolling segment and elevated side counter-weights.

as wide as desired or a number of similar structures can be disposed side by side and coupled together so as to be operated as a whole or left detached and indepen-

in the opposite direction, until the leaf has descended below the 40 degrees mark, when, the power being brought in once more, the bridge is returned to its horizon-



FOUR SINGLE-LEAF DOUBLE-TRACK SCHERZER ROLLING LIFT BRIDGES, SIDE BY SIDE, FORMING AN EIGHT-TRACK STRUCTURE ACROSS THE SHIP CANAL, CHICAGO.

This is the widest and heaviest bascule bridge in the world.

dent. Similarly, the idea is as applicable to double as to single-deck bridges, where the exigencies demand the use of one level for railway and the other for vehicular business.

Counter-weighting can be carried out upon such lines that the centre of gravity falls in the centre of the rolling segment. In this case in moving the bridge it is only necessary to overcome the resistance due to friction. By such an arrangement, directly the interlocking devices are withdrawn, the leaves will rise slowly until they assume an angle of 40 degrees, the backward rolling and upward movement being secured without any power whatever. The application of power to open the bridge still wider is very slight, and then, when the moment arrives to close the bridge, the counter-weight, forming a pendulum as it were, swings slightly

tal position. One advantage of this method is that should anything go wrong with the mechanism the leaf cannot fall from its elevated position. The energy consumed in operating the bridge is so small as to be a negligible quantity; indeed, it is so low that in many instances the authorities working the bridge do not trouble to levy charges for the opening operation.

So far as construction is concerned, interference with the navigable channel is reduced to the minimum. The leaf is erected in the vertical position, and upon completion is swung, to be taken up by the operating machinery. While the majority of bridges of this type which have been built up to the present are designed for utilitarian purposes purely and simply, it can be adapted to any artistic requirement that may be desired, so that æsthetic considerations need not necessarily be ignored.

Some remarkable bridges have been carried out upon this principle, especially in the land of its origin. The New York, Newhaven, and Hartford Railroad was presented with a puzzling proposition when it essayed to improve the facilities for entering and leaving the huge South Terminal station at Boston, Mass. The banks on either side of Fort Point Channel are low-lying, the waterway is busy, the tracks had to be compressed into six, and the engineers were pushed for room owing to the close proximity of swing bridges. Moreover, in order to cross the waterway it was necessary to run at a very acute angle. The situation was discussed very carefully owing to the strict character of the limitations, but at last it was

the first six-track bridge to be built upon this principle, but in operation it has proved completely successful. A 50 horsepower electric motor is sufficient to operate each double-track span of 144 feet, while the whole bridge is controlled and worked by one man.

Another large installation, unique at the time, was the building of an eight-track bridge in order to cross the Chicago Drainage and Ship Canal. In this undertaking three railway companies were concerned, and their lines all run side by side. Consequently when the question of crossing the canal arose, they co-operated. At first it was decided to provide a swing bridge 399 feet $2\frac{1}{2}$ inches in length by 116 feet wide, mounted on a turntable



275-FOOT DOUBLE-LEAF DOUBLE-TRACK SCHERZER ROLLING LIFT BRIDGE ACROSS THE CHICAGO RIVER AT THE ENTRANCE TO THE GRAND CENTRAL STATION, CHICAGO.

This is the longest double-leaf bascule bridge in the world.

decided to instal a six-track Scherzer rolling lift bridge in three sections, duplicates of one another, two roads to each, and to be coupled so as to be operated simultaneously or independently. This was

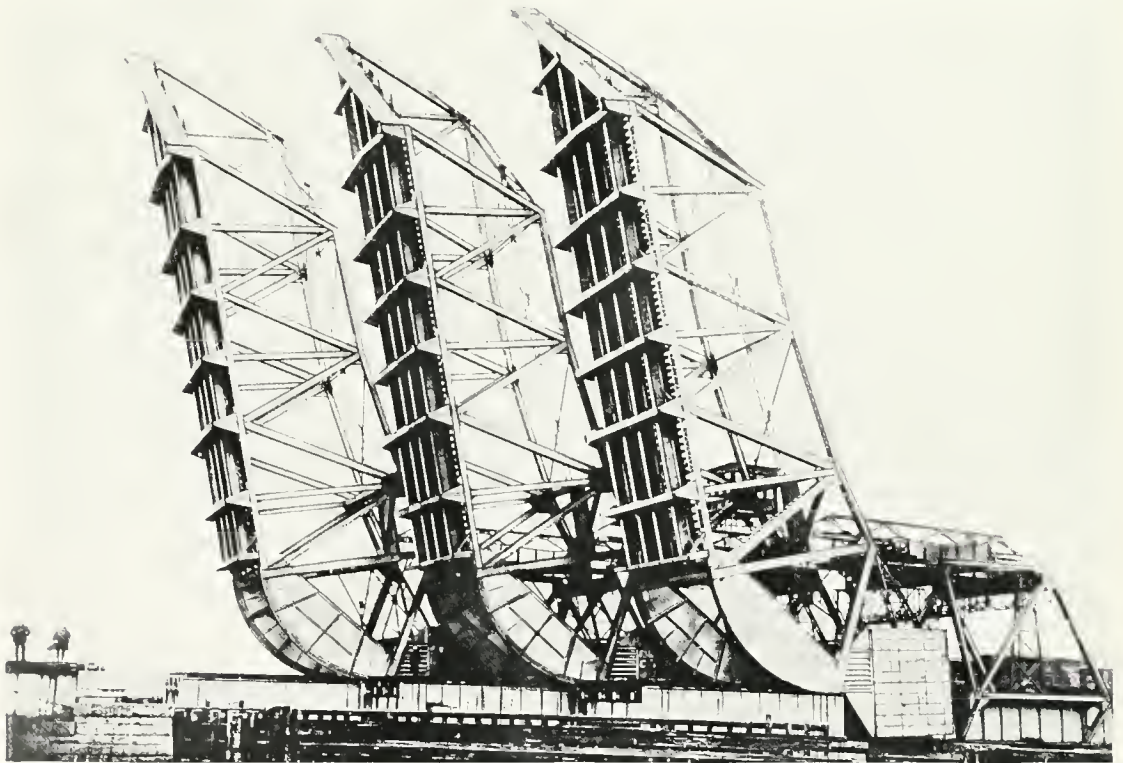
78 $\frac{1}{2}$ feet in diameter. Six tracks were to be laid upon the inside of the bridge, while one was to be provided on either side of each truss, the floor beams being extended for the purpose. Ultimately, however, the

railway authorities informed the Trustees of the Sanitary District of Chicago, who were footing the bill, that they could not accede to the proposed plans, because, in the event of a mishap to the bridge the whole of the eight roads would be blocked, while, owing to the constriction of the navigable channels on either side of the central pier whereon the turntable was to be mounted, large vessels would have to proceed slowly and carefully, and thus the interval of interruption to the railway traffic would be extended unduly.

Thereupon the authorities advertised for fresh designs, and the Scherzer proposal was selected out of seven submitted plans. Furthermore, the company operating the patents offered to complete the structure for £68,428. These plans meeting with the unanimous approval of the authorities and railways, the contract was placed. The bridge comprises four through

spans placed side by side and in duplicate, each carrying two sets of metals. This is the most ambitious example of Scherzer bridge building that has been attempted. At this point the waterway is 394 feet wide, but 120 feet clear was considered to be adequate for navigation purposes, and so the foundations for the rolling lift spans were set out into the river, the approaches on either side being carried over deck truss spans. The bridge, set at an angle of 63 degrees to the centre line of the waterway, has an over-all length of $123\frac{1}{2}$ feet, each section carrying two roads, being 29 feet wide.

The invention has met with approval among British engineers. The late Sir Benjamin Baker, the eminent engineer and designer of the Tower Bridge, was the first to introduce it into England by installing such a bridge across the River Swale for the South Eastern Railway.



THREE SINGLE-LEAF DOUBLE-TRACK SCHERZER ROLLING LIFT BRIDGES, FORMING A SIX-TRACK STRUCTURE SPANNING FORT POINT CHANNEL AT BOSTON, MASS.

Either leaf may be opened independently if desired.



Photograph supplied by the Great Northern Railway.

A GREAT NORTHERN "FLYER" PASSING THROUGH HADLEY WOODS

Famous Expresses—II

CRACK TRAINS AND THEIR RECORDS ON BRITISH AND AMERICAN TRUNK LINES



ONE of the most outstanding features of British railway operation of to-day is the development of what may be termed the 100-miles express traffic and the long-distance non-stop run. The former has been responsible for a pronounced shrinkage of time between the metropolis and the various provincial commercial centres, such as Birmingham and Bristol, while the latter has reduced the tedium of travelling over long distances very appreciably.

The long-distance non-stop express was brought within the range of commercial possibility by the perfection of the means enabling a train to replenish its water-tank while travelling at full speed. The idea is ingenious and very simple. A narrow, longitudinal, shallow trough is laid centrally in the four-foot way, upon a suitable stretch of level line. At each end the floor of the trough is sloped from

the maximum depth to zero in order to facilitate the entrance and emergence of the scoop device which is lowered into the trough and through which the water is forced into the tank of the locomotive.

As a result of this innovation, the present limit of an engine's run without a stop is controlled either by the fuel capacity of the locomotive or the physical endurance of the crew, the latter more particularly. Precisely what can be done in this connection on British railways was revealed by the London and North Western special, comprising an eleven-coach train with a double-header, which ran from Euston to Carlisle, a distance of 299 miles, without a stop, on July 19th, 1903; while the Great Western has a scheduled train which runs from Paddington to Plymouth daily, a distance of $245\frac{3}{4}$ miles, without a stop.

The numerous advantages accruing from the ability to pick up water while travelling at 60 miles or so per hour, introduced upon the British lines, did not fail to im-

press American railways. The invention, however, is not so imperative upon the North American continent, seeing that the

of making time, but they found it an excellent means of combating a pest which is peculiar to the railways of the United States.



FRONT VIEW OF A GREAT NORTHERN EXPRESS LOCOMOTIVE.

distance which a train shall travel under one engine is limited severely. Notwithstanding this handicap, however, the divisional points, as these engine-changing stations are called, in some cases are spaced somewhat widely apart—up to about 150 miles. Under these latter circumstances, and especially upon the Eastern railways, the water trough was adopted, and the railways not only received considerable benefit from the innovation, in point

enabled to make clear runs between the divisional points. When the task was completed the Limited set out one morning with a hobo concealed beneath the first coach behind the engine, who chuckled to himself that he would have a quick run to Chicago. The train was making a merry speed, and the illicit traveller was dozing peacefully. Suddenly he was immersed in the finest shower-bath he had ever encountered in his life. He

The *genus hobo* is a serious factor in American railway operation. He represents a traveller who, on principle, considers that railways should carry him from place to place for nothing. A hobo, whether he can or cannot afford the fare, will never pay; he prefers to steal a "lift," either by taking up a position among the tie-rods beneath the carriage, standing against the connection forming the corridor between two coaches, or lying prone upon the roof. The first-named seat is the most favoured, and although the couch may be hard and uncomfortable it is preferable to the "blind" and the roof.

One Atlantic seaboard railway had laid water troughs at various points upon its road between New York City and Chicago for the benefit of its crack expresses, which thereby were



THE NIGHT MAIL.

knew nothing about the new idea for picking up water *en route*. Upon the scoop being lowered, the water was thrown out in volumes, and he received the full brunt of it. When the train pulled up at the next divisional point, the train crew perceived a limp, bedraggled object of human misery emerging from beneath the baggage car. The officials laughed so uproariously at the discomfiture of the hobo that they let him

supremacy waged by the West and East Coast routes from 1888 to 1895, between London and the North, the Great Northern locomotives put up some fine running performances. In the bid for premier position it inaugurated non-stop runs between London and Grantham, a distance of $105\frac{1}{2}$ miles. Now the crack expresses accomplish the $175\frac{3}{4}$ miles between London and Wakefield (*via* the Great Northern and



Photograph supplied by the Great Northern Railway Co.

THE LATEST TYPE OF GREAT NORTHERN EXPRESS LOCOMOTIVE.

These powerful Atlantics (4-4-2) when ready for the road, weigh, with tender, 112.5 tons.

go, knowing full well that he would communicate to his pals the risks attending travelling on the Limited.

Among the many British expresses probably none is so familiar to the travelling public as the "Flying Scotsman," as it has been described colloquially for so many years, although to-day this train has lost a considerable amount of its peculiar glamour owing to the number of other fast trains which go the East Coast way. For many years the Great Northern Railway held paramount position in point of speed. Its route is favourable to pace, because it is free from sharp curves and gradients, the summit being only 345 feet above sea level. In the days of the single drivers the Stirling locomotives, with their 96-inch driving wheels, achieved a world-wide fame.

In the memorable ding-dong battle for

Great Central joint line between Doncaster and Wakefield), and between London and Doncaster, 156 miles, without intermediate stops. The northern extremity of the main through line of this system is at Shaftulme Junction.

What the singles were to the closing years of the nineteenth century, the Atlantics are to the present decade—powerful representatives of speed. This class of express locomotive made its first appearance in this country upon the Great Northern Railway. The latest Great Northern locomotives of the 4-4-2 class, while not so powerful as those used upon the American railway where this type was born, are equal to their prototypes in point of pace. The cylinders have a diameter of 20 inches with a stroke of 24 inches. The boiler has a diameter of 66 inches, with a length of 16 feet between

the tube plates. The fire-box is 143 square feet; the total heating surface of the tubes is 1,884 square feet; superheater, with which the latest examples are equipped, 570 square feet, giving an aggregate heating surface of 2,597 square feet, while the grate area is 31 square feet. Steam is used at a pressure of 170 pounds per square inch. The drivers are 80 inches in diameter, and the wheel base of engine 26 feet $4\frac{1}{4}$ inches. The total weight of the engine in running order is 69.4 tons, of which 18 tons is disposed upon each driving axle, thereby giving 36 tons available for adhesion. The six-wheeled tender, with capacity for $6\frac{1}{2}$ tons of coal and 3,500 gallons of water, weighs 43.1 tons, bringing the total weight of the locomotive ready for the road up to 112.5 tons.

These engines now work all the fastest express services of the system, hauling trains varying from 200 to 300 tons in weight. They put up some very fine running performances such as the timed run of 120 minutes for the 105.45 miles between London and Grantham, an average of 52.72 miles an hour, and from London to Doncaster, 155.96 miles in 180 minutes—51.95 miles per hour. The crack trains to the far north running the East Coast way, a service which is maintained by the Great Northern, North Eastern, and North British conjointly, are known far and wide, Edinburgh, 396 miles from King's Cross, being brought within $7\frac{3}{4}$ hours' travelling of the metropolis.

Indeed, the communication between London and the Scottish centres is of a very complete character, three routes being available—the East Coast, Midland, and West Coast respectively. The Midland way to the north terminates at Carlisle, 308 miles from the metropolitan terminus at St. Pancras, many of the most important provincial centres being tapped en route. North of Leeds to the Border the line

traverses very broken country, where the discovery of an easy alignment proved no easy matter. At Carlisle the Midland meets the Caledonian Railway, whence the traffic is worked to Scottish points.

The express traffic may be divided broadly into two classes. There is the through business to the North, and that to the Midland centres—Leicester, Nottingham, Derby, Sheffield, Leeds, Manchester, etc. There are two notable long non-stop runs, the longest being between London and Shipley, in the summer—a distance of 206 miles, and between the metropolis and Masborough, during the winter—162 miles. The Sheffield expresses constitute a notable feature of the service, the 158½ miles being covered in 180 minutes, representing an average speed of nearly 53 miles per hour.

Two broad classes of locomotives have been designed by Mr. Henry Fowler, the chief mechanical engineer to the system, for the operation of the crack express service. Both are of the 4-4-0 class, one being simple and the other compound. The latest compounds of the 1000 class have three cylinders, one high pressure, with a diameter of 19 inches, and two low pressure, of 21 inches diameter, by a common stroke of 26 inches. The drivers are 84 inches in diameter, and the boiler steam pressure is 220 pounds per square inch. The simple machines of the 990 class have cylinders of $20\frac{1}{2}$ inches diameter, by 26-inch strokes, while the diameter of the driving wheels is $78\frac{1}{2}$ inches. Owing to the utilisation of the Schmidt superheater, the working pressure of the steam is reduced to 180 pounds per square inch. The weights of the locomotives of the two classes differ very slightly, the engine and tender of the 1000 class in working order weighing 105.8 tons, while the 990 class under similar conditions turn the scale at 106.2 tons.

The two types of locomotives are designed for fulfilling the opposite conditions pre-

Some G.N.R. Runnings.

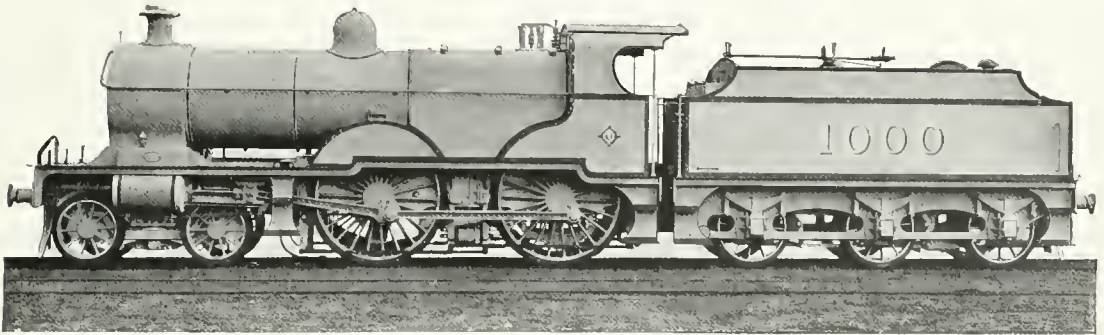
Midland Express Engines.

The Midland.

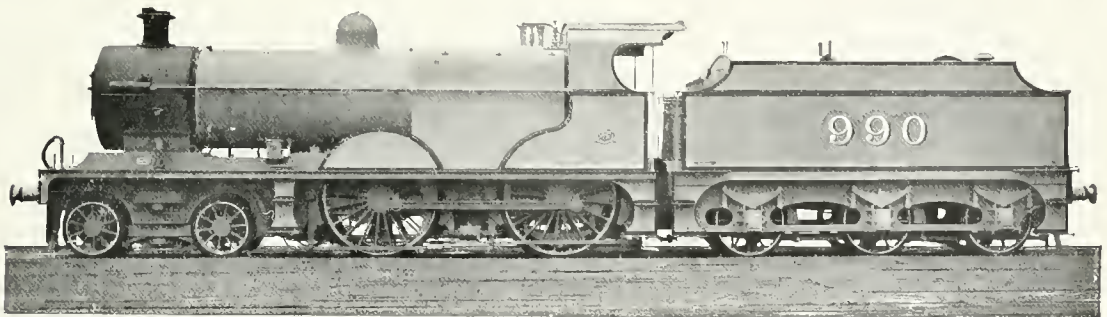
vailing in operating the Midland express traffic. As a rule the Scotch expresses are worked over the easier division of 198 miles between London and Leeds by the 1000 class compounds, while the 990 class take the trains over the second stretch of 110 miles to Carlisle which bristles with

locomotive effort, which has culminated in the "Sir Gilbert Claughton" 4-6-0 class, which has been designed to handle this business over the northern division of the system between Crewe and Carlisle.

Upon the London and North Western Railway it is no uncommon circumstance



THE "1000" COMPOUND CLASS WEIGH 105'8 TONS, AND USUALLY WORK THE SCOTCH EXPRESSES BETWEEN LONDON AND LEEDS.



Photographs supplied by the Midland Railway Co.

THE "990" CLASS WEIGH 105'2 TONS, AND AS A RULE WORK THE SCOTCH EXPRESSES BETWEEN LEEDS AND CARLISLE.

TYPES OF MIDLAND EXPRESS LOCOMOTIVES.

heavy gradients, the summit at 1,166 feet being gained between Hawes Junction and Kirkby Stephen.

The West Coast route is that offered by the London and North Western Railway. Here, again, conditions similar to those experienced upon the Midland in the northern part of the journey are encountered, the most difficult section being the six miles' pull over Shap Fell, where the summit level of 914 feet is reached, with a maximum rise of 1 in 75. The increasing traffic and the augmented weight of the trains engaged in the Scottish service resulted in a further demand for greater

for the locomotive to be called upon to handle a train ranging from 350 to 400 tons. Ten years ago the business was fulfilled adequately by the "Precursors" and "Experiments," but the exigencies of weights and speeds compelled a more powerful machine. Accordingly, the chief mechanical engineer to the system, Mr. Cooke, decided to meet these later requirements by adopting superheating, which had established its advantages upon the Continent. The outcome was the "George the Fifth" class, which is really an improved "Precursor" with superheater. The drivers are of the same diameter, 78 inches, and





Photograph by permission of the London and North Western Railway.

A "HEAVY" LONDON AND NORTH WESTERN "FLYER."

The Scotch Express climbing the steep incline leading out of Euston.

the boiler is precisely the same, except for the superheater tubes. The cylinders have a diameter of $20\frac{1}{2}$ inches, with a stroke of 26 inches. The aggregate heating surface of the tubes and fire-box is 1,547.15 square feet, and that of the 24 superheating elements, which are of the smoke-tube type, 302.5 square feet, making a total heating surface of 1,849.65 square feet. Steam is used at a pressure of 175 pounds per square inch. The weight of the engine in running order is 59.85 tons, and with the tender in loaded condition, 99.1 tons.

The year following the appearance of the "George the Fifth" class, an improved "Experiment" was brought out

Other L. & N.W.R. Express Locos. for working the express passenger trains over the difficult northern division between Crewe and Carlisle. This 4-6-0 type was named "Prince of Wales" class, the distinction being the addition of a superheater. The engine has nominally 72-inch drivers, with cylinders of $20\frac{1}{2}$ inches diameter by 26-inch stroke, and the steam is used at a pressure of 175 pounds per square inch. The total heating surface is 1,897.5 square feet. The weight of the engine in running order is 66.25 tons, and of the tender—carrying 3,000 gallons of water and 6 tons of coal—39.25 tons, making 104.5 tons in all.

This railway has cultivated its long-distance traffic very assiduously, and there are over fifty trains which make daily non-stop runs of 100 miles or over. The longest regular run of this character is that between London and Liverpool, the $192\frac{1}{4}$ miles being covered in 208 minutes, giving an average start-to-stop speed of 55.5 miles per hour.

During the past few years the trains of the Canadian railways have undergone remarkable acceleration. Pride of place is occupied by the "International Limited," of the Grand Trunk system, which every day throughout the year covers the 840.6 miles between Montreal

and Chicago in 22 hours—an average speed of 38.2 miles per hour. The fastest section of the journey is over the 334 miles from Montreal to Toronto, which is completed in $7\frac{1}{2}$ hours, an average of 44.5 miles per hour.

This Limited is not only the crack train of Canada in point of speed, but also with regard to comfort and luxurious equipment. It comprises six coaches—combination baggage car, first-class coaches, dinner, parlour, and Pullman drawing-room, which are the finest expressions of their work in the country.

The train is drawn by one of the latest type of Pacific 4-6-2 superheated locomotives, having 73-inch drivers. The total heating surface of tubes is 3,254 square feet, and of fire-box 163 square feet, giving an aggregate heating surface of 3,417 square feet. The grate area is 50.62 square feet. The weight of the engine is 228,000 pounds, while the tender, with 8,000 gallons of water and 10 tons of coal, weighs 150,000 pounds, giving a total weight, ready for the road, of 187.5 American tons, while the total over-all length is 72 feet 4 inches.

There is one feature of American train working which often perplexes and confuses, as well as amuses, the stranger from this side. Officially, the trains are operated under numbers. Thus while the "International Limited" is the colloquial description, its official designation is train No. 1. But it does not retain this distinction throughout its flight from Montreal to Chicago. Upon reaching Toronto No. 1 mysteriously disappears; it becomes Train 15 and continues as such on its westward journey for another 118 miles to London. Here there is another shuffle, the train becoming known as No. 5. As such it enters Chicago. One would think that on the return journey from Chicago to Montreal it would retain its colloquial name. But it is not so; it starts off as No. 14. It clings to this description until it has covered

A Curious System.

334 miles of its eastward journey, when it blossoms forth as Train 4 for the remainder of the journey to Montreal. The west-bound express leaving Montreal at 9.40 a.m. similarly is known as Train 7 to Toronto, where it becomes Train 17 to Port Huron. Here it reverts to its former description and continues to Chicago as Train 7.

Another magnificent American train which has compelled attention during the past few years is the "Olympian," running between Chicago and Seattle over the Chicago, Milwaukee, and St. Paul Railway. It is a seven-car train, Pullman throughout, representing a dead weight of some 300 American tons. It runs in both directions daily, leaving Chicago

at 10.15 p.m. for the Pacific north-west and Tacoma for the Great Lakes at 8.45 a.m., the 2,201.2 miles between the two termini being covered in 72 hours westward and 86 hours respectively—30.5 and 25.6 miles per hour. The train is replete with every convenience, comprising smoking compartment in the observation car, private sleeping compartments complete with furniture, bath-room, and many other little conveniences which serve to relieve the tedium of travel. The train carries a miniature, yet complete, electric lighting station, together with an electrically-driven vacuum cleaner, with which its operator, who scours the cars every day *en route* therewith, will vacuum-clean your clothes upon request.



THE "OLYMPIAN" PASSING THROUGH THE MONTANA CANYON.



'ON THE GRADE.'

A Railway which Goes to Sea

HOW KEY WEST—"AMERICA'S GIBRALTAR"—IS LINKED UP WITH THE MAINLAND



LYING off the coast of Florida, and about midway between the mainland and the island of Cuba, is a small low-lying island. This is Key West, the most southerly outpost of the United States, which, as a naval station, has become known far and wide as "America's Gibraltar."

During the Cuban campaign this base of operations loomed large in the public eye, but it suffered from one serious disadvantage: it was isolated completely. Approach was possible only by water. Running shorewards from this insular station, in a gentle curve, is a chain of coral islands, designated "keys," divided by wide deep channels.

It is quite possible that Key West, after Cuba had been wrested from the Spanish, might have relapsed back into an unknown and uncared-for dot of coral washed by the waters of the Atlantic. But one great

force saved it—the railway. A dreamer of conquest conceived the trail of steel stretching from this island to the mainland, leaping from key to key. Thus the future of Key West became assured. The fact that it is 300 miles nearer the Panama Canal than any other American port secures its naval and military value, while the fact that it is in direct railway communication with the great centres of the United States and Canada imparts to it a significance which as yet cannot be estimated.

The linking of Key West with the mainland constitutes one of the most thrilling and daring conquests of the railway. At the same time its fulfilment is due entirely to one man, of remarkable perspicacity and dauntless courage—Mr. Henry M. Flagler, a colleague of the Rockefellers.

In 1883 this financial and organising magnate was forced to take a spell of rest and recreation to recuperate. Instead of coming to the famous resorts of Europe,

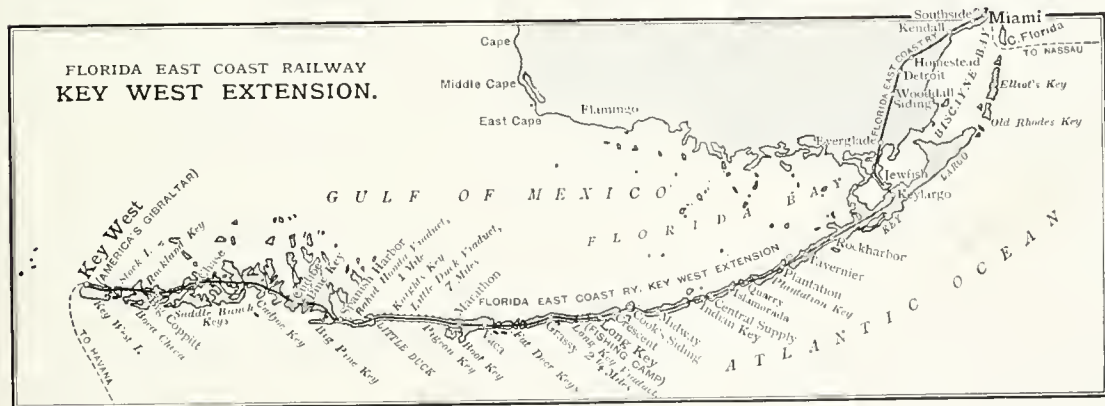
he went to Florida, to a point as far south as the railway could take him. This was St. Augustine. It was by no means a pleasure trip to gain this point, as travelling comfort and convenience, in the generally accepted sense of the word, ended at Jacksonville, the capital of the State. True, the steel highway went beyond, but it was a narrow gauge line which ran southwards to St. Augustine and Palatka—a highway in an advanced stage of senile, or rather premature, decay.

St. Augustine itself was a striking counterpart of Sleepy Hollow, but Mr. Flagler found that it enjoyed an ideal winter climate, while he saw that the surrounding country possessed vast agricultural possibilities if exploited in a progressive manner. Americans were in the habit of seeking the European Riviera in the winter, and yet they did not know that at their very doors, within a few hours' run of their offices, was a clime equal in every respect to that of the Sunny Mediterranean.

The holiday-making millionaire resolved

southern bank, and all traffic had to be carried across the waterway by ferry. From this humble beginning a comprehensive railway system grew rapidly. In 1887 Mr. Flagler bought up the narrow-gauge line running south from St. Augustine to Dayton, and a year later acquired another line running from St. Augustine to Palatka. Both these at once were changed to the standard gauge, and in 1889 a bridge was thrown across the St. John's River to supersede the ferry. A huge hotel was completed, and the American Riviera commenced to grow with amazing speed.

Simultaneously the favourite resort, Ormond, began to grow, together with Daytona, famous for its stretches of sands, whereon the highest motor speeds in the world have been attained. Not satisfied with this measure of success, the guiding spirit commenced to drive his railway farther to the south, and in 1894 another glorious resort, 366 miles south of Jacksonville, came into being. Still he did not



to open the eyes of his compatriots. He would develop St. Augustine and Southern Florida into a rival to Europe's winter playground. In 1885 he bought up the narrow-gauge railway running to Jacksonville. Without delay he tore up the old line and relaid it with the standard gauge. At that time the broad waters of the St. John's River were a serious handicap. The St. Augustine railway ran up to the

pause. While on one of his periodical visits to the south Mr. Flagler hired a spring wagon, and with this primitive conveyance set out on an exploration trip, tolerating all the discomforts incidental to an overland journey through an unpeopled country with the greatest good humour. He travelled as far as Miami, on Biscayne Bay. Here he found a magnificent natural harbour, with similar, if not superior,

climatic and agricultural conditions; accordingly he once more set his engineers to work to lay the track to Miami, which was entered in 1896.

Then came a halt. There was no idea of carrying the railway farther. However, the tempting stories of the attractive climate and rich soil in the lower part of the peninsula, combined with the growing Cuban trade, proved irresistible. Then in a flash came the thought, "Why not take the railway right into Key West?"

It was a bold proposal, but the governing hand had become familiarised with the characteristic of the coral keys, and the waters which laved them. He called in his first lieutenant, Mr. Parrott, the general manager, to whom he adumbrated his idea. They discussed the commercial possibilities of such a project, and as the railway manager saw no reason why it should not be accomplished, he was requested to investigate the proposal more intimately, and to report upon its feasibility. Meanwhile it was decided to push 28 miles farther, to Homestead.

The surveyors set out in 1904, and drove their reconnaissance in all directions.

South of Homestead was a forbidding stretch of country where the mainland is low-lying and only saved from inundation by the coral barrier which covers the sea coast rim. The "Everglades," as they are called, had been acknowledged to be only fit for the abode of the alligator, and there was a general disposition to permit the saurian to remain in undisputed possession of the dismal swamp. While one corps of surveyors was wading through the lagoons another small army was scouting and probing among the keys, studying the tides, water channels, wind, currents, storms and hurricanes which assail these isolated coral reefs.

As the reports came in Mr. Parrott weighed them up, studied the different

proposed routes, and finally evolved one which he considered would meet all requirements, and which was the best possible.

Then he revealed the fruits of the surveyors' labours to his chief. It was a startlingly daring proposal; the cost would be prodigious. No estimate could be advanced, as the unknown and unexpected lurked on every hand. But the financier was not perturbed by the expenditure. Finally, he turned and said, "You are convinced that this railway can be built?"

"Positive."

"Right; go ahead."

There the discussion ended.

The general manager set out to complete the task of carrying the railway to Key West, 128 miles beyond Homestead, 14 miles of which lay across the low-lying mainland, and the remaining 114 miles over the sea-swept coral islets.

The first move was to find an engineer of sufficient ability, resource, and courage to attack the task. Fortunately, at Tampico, across the Gulf of Mexico, large docks were

being built at the time. Some pretty problems had tripped up the engineer on this enterprise from time to time, but he had handled them with excellent skill and ingenuity. Mr. Parrott decided that this was the very man for the new undertaking; so accordingly he approached Mr. Meredith and invited him to assume responsibility for the railway project. The request was accepted, and, as it proved, a better man could not have been found.

From the moment he attacked the enterprise its successful issue never was in doubt for a moment. The first sod south of Homestead was turned in April, 1905. Driving through the "Everglades" was monotonous. The ordinary means of building the embankment by the aid of steam shovels was useless, as the soil is entwined thickly with the straggling roots of swamp scrub and mangrove trees. So a new

**Why not
Key West?**

**Mr. Flagler's
Decision.**

**The First
Surveys.**

**The Engineer
Found.**

method was adopted. Powerful dredgers were brought up, and they gnawed their way forward through the marshes digging a canal on either side of the grade. Their orange-peel buckets tore up the roots and debris and piled them in a symmetrical low-lying ridge from Homestead to Jewfish Creek, where the railway leaps out to sea.

But it was on the sea stretches that the greatest demands were placed upon engineering skill and organisation. Taken on the whole, the islets between the mainland and Knight's Key were found crowded somewhat closely together, so that the sea stretches were reduced in length. Between some of the islands the water was found to be so shallow as to enable an earthen embankment to be raised. But here and there the water gap was found to be very wide and deep, demanding trestling, masonry viaducts, and steel bridges. Fortunately, the engineer was spared a tedious search for suitable foundations, which invariably is associated with sub-aqueous work, inasmuch as the sea bed is formed of hard coral rock.

At the same time, as many of the channels between the keys are used by vessels in passing to and from the Mexican Gulf ports, the rights of navigation had to be respected. This situation was met by spanning these interruptions by swing bridges. Between the mainland and Knight's Key each swinging span is 99½ feet in length, so that ample clearance is offered to enable vessels to pass through.

While the task bristled with engineering problems of a peculiar character, the care of the thousands of men engaged on the grade was far more searching. It was impossible to house them on the land, so floating quarters were prepared. Flat-bottomed scows were built, on which were erected timber barracks, and these were moored in close proximity to the scene of operations, the men passing to and fro in small boats. Steamers were deputed to

make the round of these floating homes with supplies of provisions, etc., while stern-wheel craft were brought down from the Mississippi to move these floating homes to and fro, as well as tugging supplies of drinking water stored in capacious conical water tanks. Every drop of this commodity had to be brought over long distances to the scene of operations.

At Miami a large hospital was established, whence were hurried all those who were stricken down by serious accident or disease; while along the grade were distributed other smaller medical depots to extend temporary aid and to minister to trivial mishaps and illness. Notwithstanding the fact that the navvies were of every shade and colour, and were housed in unavoidably confined quarters on the floating barracks, a remarkably clean bill of health was carried throughout the seven years work was in progress. True there was a certain mortality, but the abundant supplies of good food, medical care, and the Florida climate frustrated all attempts of an epidemic to secure a foothold.

The floating equipment for the prosecution of the work was just as varied as the toilers themselves. It was a big fleet of schooners, stern-wheel steamers, floating derricks, dredgers, pile-drivers, concrete mixers, and what not, which haunted the grade night and day. Floating yards for handling the material were established, whence the steel, cement, sand, and gravel were prepared for the raising of the arched viaduct, the building of the bridges, or the provision of piers. One of the most notable attributes was the fleet of motor launches which flitted to and fro with the foremen, resident engineers, messengers, and others who had to pass from one point to another with the minimum of delay.

The first big stretch of viaduct over the sea arose when Long Key was reached. This is a concrete arch structure two miles in length, comprising 180 semi-circular

Between
the Keys.

Health on
the Grade.

arches, each of 50 feet span, and with the rail level elevated 30 feet above high water. Being exposed to the full brunt of the hurricane's attack, and the sweep of the big breakers which get up during a tropical

on the reinforced concrete principle, but the builders, not being certain of the behaviour of the steelwork under the action of salt water, the arches have been so designed that the steel reinforcement has to perform



THE RAILWAY EAST OF PIGEON KEY, SHOWING PIERS AND BRIDGE CONSTRUCTION.

tempest, this structure is of heavy design. The sites of the piers were marked out, and then the dredgers removed the layer of sand covering the rock bottom. A cofferdam was towed up, brought over the cleared area, and then sunk. By aid of a floating pile-driver piles were driven into the seabed until they refused to move an inch farther—generally at a depth of 4 to 6 feet. In this way, not only was a foundation secured for the pier in the event of the rock being undermined, and a protection against overturning obtained, but by driving the piles the engineers were able to ascertain whether the rock was solid, or whether it contained any faults, cavities, or upper hard crust.

A layer of concrete was dumped upon the rock to a depth of 5 feet or so, and upon these plinths commenced the piers proper. The superstructure has been built

no responsible work. Timber forms or moulds were employed for the building of the arches, which were built alternately, so as to guard against expansion cracks. The stone for the concrete was blasted out of the sea-bed in shallow water near by, and lifted by orange-peel buckets on to the scows to be crushed and mixed with the cement in capacious mechanical mixers.

Where the railway crosses the shallow water openings and the low swampy keys dredges and travelling excavators served to pile up the solid earthen embankment. In some places pipe-lines were laid down along the centre of the permanent way, and the ballast pumped through these conduits was deposited where required, the water draining away. Owing to the saturated condition of the soil some time elapsed before the water dried out. Furthermore, the roots drying under the hot southern

sun were converted into matchwood; consequently care had to be taken to protect this inflammable material from fire, while to avoid damage from erosion the slopes were dressed with rip-rap. This protection, however, was not satisfactory, as the stone dressing was washed away somewhat easily, so marl was used instead. This material was dredged and loaded into steel dump cars, which were hauled to the required points and discharged. The marl spread out so as to form a flat slope. Exposure to the air hardened it into a solid coating. The wave action which demolished the rip-rap fails completely to exercise any ill-effects upon the marl. Altogether some

Miami, within sight of the line along which the expresses now thunder to and fro, is a rough, massive monolith of granite carrying the inscription:

"In memory of Joseph Carroll Meredith, chief engineer in the construction of the Key West extension of the Florida East Coast Railway, who died at his post of duty, April 20th, 1909. This memorial is erected by the railway company in appreciation of his skill, fidelity, and devotion in this last and greatest work of his life."

Mr. Meredith's mantle descended upon his right-hand man, Mr. William J. Krome,



THE FINISHED EARTHEN EMBANKMENT IN THE "SHALLOWS" BETWEEN THE KEYS—AS SOLID AS A ROCK

49 miles of the line have been built in solid earthwork and protected in this manner.

When the line was within measurable distance of Knight's Key, the engineer-in-chief was stricken down by an insidious disease, to which he succumbed. At

who not only carried his late chief's work into Knight's Key, but subsequently drove the project to its objective, Key West.

Knight's Key was reached in February, 1908, and here a short pause was made to enable arrangements to be completed for

the attack upon the second section. The first stretch of 7 miles bristled with difficulties, as it ran through water ranging from 18 to 22 feet in depth. Here the concrete arch viaduct was impossible, so a steel bridge was adopted. This is a massive piece of work, comprising 316

the deeper part of the strait. The total length is divided into 36 spans—9 deck girder spans each of 80 feet, 13 spans of 128½ feet, 13 each of 186 feet, and one span of 247½ feet, carried on similar massive concrete piers.

When the bridging was commenced out

of Knight's Key the setting of the steel was let out to contract, but this arrangement not proving satisfactory, the work was taken over and completed by the railway forces. The deck girder spans were floated out on barges, and were lifted and set by floating derricks. This method was far more rapid than that followed by the contractors. On one occasion the railway gangs placed six spans



"THE WATER SPECIAL."

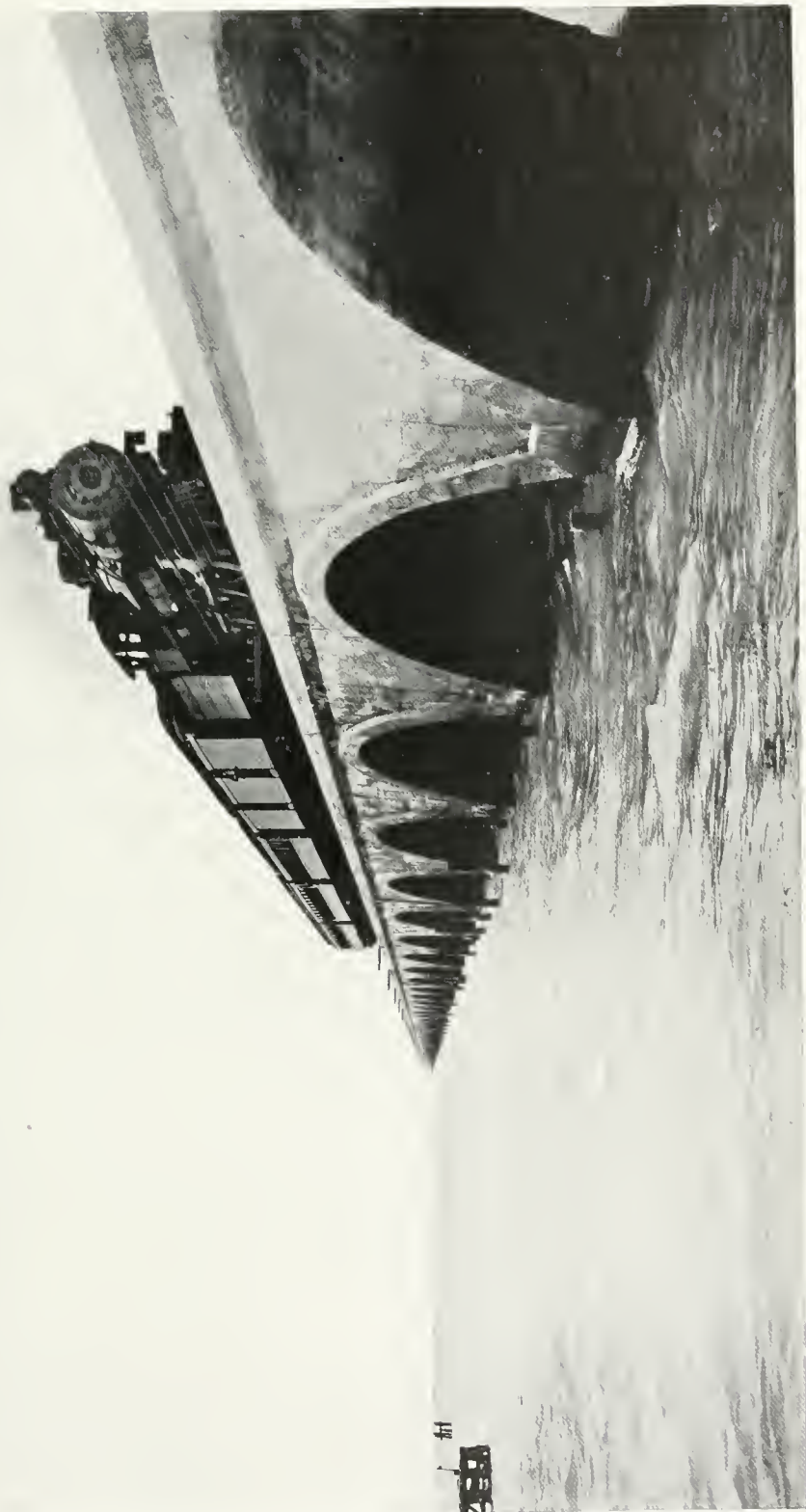
Two conical wooden tanks, each of 3,000 gallons capacity, are mounted upon each truck.

deck girder spans each of 80 feet, 19 spans of 59¾ feet over the deepest part, and 210 arches of 53 feet span across the shallower waters, giving a total length of 37,545½ feet of steel work. In addition, as the railway crosses the navigable Moser Channel, a swing drawbridge is placed over this fairway. This is of the through truss type, 253½ feet in length, and is of interest because the mechanism for operating the bridge is driven by a petrol engine.

At Bahia Honda another wide stretch of sea entailed bridging to the extent of 5,100 feet. This part of the work was somewhat more formidable than that out of Knight's Key, because, the water running up to 30 feet deep, a through truss, instead of a deck girder bridge, was selected over

in position in four hours, while on another a span was erected in twenty minutes. In building the Bahia Honda bridge timber falsework and an overhead traveller were employed in connection with the truss spans. So carefully was the work carried out that not a single life was lost in building the 32,899 feet of steelwork comprising the Knight's Key and Bahia Honda bridges. Before Key West was reached another 2,573 feet of sea had to be crossed, but in this instance the concrete viaduct with arches of 30 feet span, was found practicable.

Will the railway stand? This has been a favourite theme of discussion ever since it was projected. The builders themselves have little apprehension on this score.



THE "OVERSEA LIMITED" EN ROUTE FOR KEY WEST.

On the viaduct speed is restricted to 15 miles per hour.

Their greatest anxiety is in regard to the best measures to adopt to protect the enormous stretches of steel comprising the bridges from the ravages of rust. The salt water sets up extensive and rapid corrosion. Up to the present no paint has been discovered which will prevent this completely. The engineers have tried, and still are testing, a whole range of so-called rust-proof specifics. The warm moist Florida air, however, appears to destroy their protective qualities, if any, within two years. Meantime, the engineers themselves have been carrying out practical experiments to solve the issue. So far they have found that their stock paint is the most satisfactory. It may be a garish yellow, but the colour enables the effects of corrosion to be detected quickly, so that precautions may be taken in time. Similarly, the railway metals, being exposed to the same destructive influences, have to be treated with a protective coating made up of paraffin, portland cement, and refined coal tar.

So far as the hurricane and the tropical storm are concerned, the works have been subjected to as fierce on-
Assaulted by slaughters of the elements as
Hurricanes. could be conceived, and yet without giving the slightest sign of capitulation to these blind forces. During 1906 a hurricane swept over the works. The engineer-in-chief had been studying meteorological conditions very closely, had noted the conditions under which these tempests arise, and had drawn up precautions accordingly, while the Washington meteorological department assisted him with timely warnings of approaching disturbances. The hurricane of 1906 was heralded, but the workmen having been scared by a similar threat in 1905 which did not mature, did not receive it seriously. So the grade was caught napping. The navvies sought refuge in their floating barracks and experienced the full onslaught of the storm. The floating homes were torn from

their lashings, and, being worse than helpless, were driven hither and thither by wind and wave. Many of the boats were smashed against the keys and wrecked, while some were blown out to sea and presumably foundered, for they were never seen nor heard of again. Many stragglers were picked up days after by passing vessels, having passed through privations untold, but when the roll-call was called, 70 men failed to answer their names.

When, therefore, another warning came in 1909, more heed was given. All the equipment was anchored safely, and the houseboats were towed to shelter. This was a fortunate circumstance, inasmuch as this storm was the most severe which ever has been known to assail the coast of Florida. Very few lives were lost, and although the wind attained a velocity of 125 miles per hour, the line escaped unscathed.

Although the railway is of an unprecedented nature, the rapidity with which it was carried to completion constitutes an outstanding feature. **Rapidity of Building.** It was the original intention to have the track finished and ready for traffic by January, 1913, but the 1911 New Year's gift to the engineers was the order to have the line open by January, 1912, at all hazards. There was a general speeding-up all round; the engineers spared no effort to win this race against time. They succeeded; and on January 22nd, 1912, the expresses from the north rolled into Key West.

The single track is laid with 70-pound rails and travelling is like rolling over an asphalt pavement, the permanent way being solid and firm. In the 129½ miles between Homestead and Key West there are 17.2 miles of bridge work, of which 11.1 miles comprise concrete arch viaducts, and 6.1 miles steel bridging, 20 miles of the track extends through shallow water, while the balance lies over the keys themselves. The terminal facilities at Key West cover an area of 134 acres, some of

which has been reclaimed from the sea by filling the shallow reaches. A commodious station has been built, together with a concrete pier 1,700 feet in length, and wide slips, excavated out of the solid rock, to enable any vessel coming into the port to be berthed.

The train service comprises two expresses daily, in addition to freight, and a water train. The crack express is "No. 87," the "Oversea Limited," a solid Pullman, which runs through from New York daily. The 522 miles between Jacksonville and Key West are covered in 19 hours 5 minutes. The second train is a local express between the two points, which completes the trip in 21 hours.

So far as the running time is concerned, an average of 27.35 miles an hour may not appear inspiring. But the train has to respond to numerous service slacks and stops when traversing the oversea section.

On the concrete viaducts and steel bridges the speed is limited to 15 miles an hour,

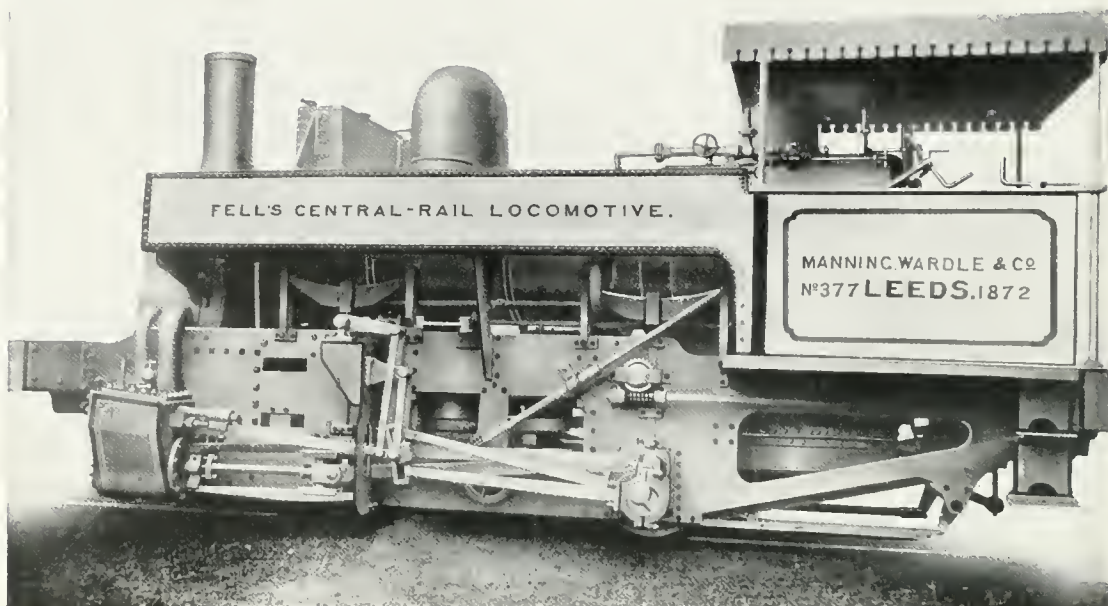
while on the reverse curves and trestles it is reduced to 10 miles an hour.

The water train is one of the most important in the whole service, seeing that all the water tanks between Jewfish and Key West have to be replenished from the mainland, no fresh water being obtainable between the two points. Each deck car is fitted with two conical wooden tanks, each containing 3,000 gallons. These are filled at Everglade Station, on the mainland, where a pumping and storage plant has been laid down. Until the railway was completed fresh water cost a halfpenny per gallon at Key West.

Towns are springing up alongside the railway, and a long string of popular resorts are coming into fashion even upon the keys themselves, where sport, rest, and recreation are offered in a kindly warm, invigorating climate. But there is one circumstance that towers above all others—as a railway-building achievement the Key West line is unique.



MOSER CHANNEL BRIDGE, 7½ MILES LONG.



AN EARLY TYPE OF THE FELL CENTRE-RAIL LOCOMOTIVE.

The First Mountain Railway

THE STORY OF THE CENTRE-RAIL LINE LAID OVER MONT CENIS IN THE
EARLY DAYS OF RAILWAY ENTERPRISE AND THE FURTHER DEVELOPMENT
OF THE SYSTEM



THE locomotive scarcely had become established upon the Continent of Europe when enterprising French engineers proposed that France and Italy should be connected by railway, so as to provide through direct communication between the North and the Mediterranean Seas. There was only one obstacle to interfere with the realisation of this dream, and that was one of extreme significance—the Alps. How to get through that barrier became a crucial question. The passes were probed through and through in the search

for a feasible route, but notwithstanding the skill and resource of the engineers one fact became only too patent—the Alps could not be overcome unless a big tunnel were driven through the rampart. It is not surprising that the advocates of the idea in 1840 hesitated to commit themselves to boring the Alps. Such a tunnel as was demanded had never been attempted up to that time. So nothing beyond discussion was done for seventeen years.

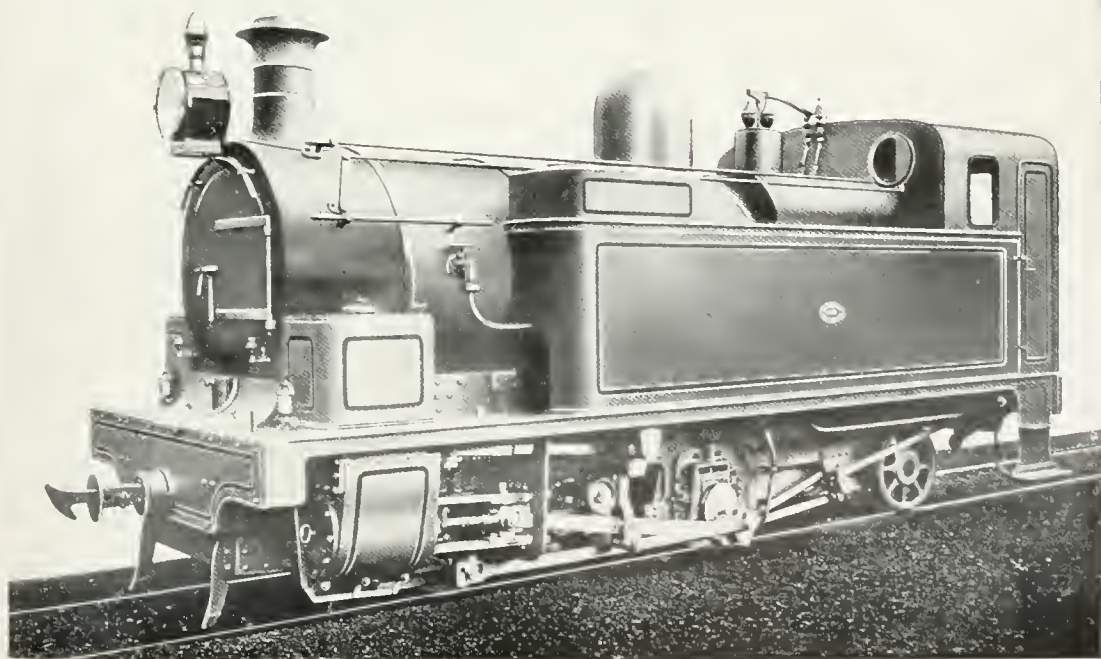
At last, in 1857, the French and Italian authorities took their courage in their hands and commenced to pierce the Alps with a tunnel 8 miles in length. The point

selected for the driving of the final link was the Col de Fréjus. It was a desperate undertaking, and its successful completion, after years of hard work and the subjugation of difficulties such as had never been encountered in railway construction up to this time, stands as an imperishable monument to the courage and skill of the French and Italian engineers.

But while the tunnel was in progress an English engineer had been working diligently upon an idea which had occurred to him, and which he maintained would eliminate the necessity to bore big tunnels. This was the late Mr. Fell. His conception was a decided innovation in railway practice. He described it as a "centre-rail" system, because between the ordinary two running rails he introduced a central third rail, available for adhesion, but in a manner different from anything then existing. The system must not be confused with the rack rail, wherein the face of the rail is provided with teeth, with which a cogwheel on the locomotive engages. The "Fell" is a pure

adhesion system. There is a double-headed rail, laid horizontally instead of vertically. The locomotive, in addition to the ordinary carrying and driving wheels, is fitted with four horizontal wheels, two set on each side of the central rail, and in such a way as to run upon the two heads of the latter. This centre rail is placed 8 inches above the level of the running rails, so as to give the horizontal wheels sufficient clearance when running over points and switches.

The third rail is carried on steel chairs bolted to ordinary sleepers, the bolts passing through the web. In this manner the rail is fixed irremovably to the sleepers, and the whole of the permanent way is bound together in a most substantial and rigid manner. The number of the horizontal wheels may be varied according to the dimensions, weight, and power of the locomotive, but four have been found adequate as a rule. Each set of wheels has its own driving unit, one set of cylinders and pistons actuating the usual carrying and driving wheels, while the second set



A RECENT TYPE OF THE FELL CENTRE-RAIL LOCOMOTIVE.

serves the horizontal wheels. The latter can be thrown in and out of action as required, so that the horizontal wheels are worked only when the centre-rail section of the road is entered. By this means it is possible to work grades up to 1 in 10 by adhesion purely and simply.

The system possesses advantages such as are not found in any other method of rail-

**Advantages of
the System.**

way operation. Owing to the perfect grip, or adhesion, secured by the horizontal wheels, the revenue-earning factor is enhanced. A Fell centre-rail locomotive will haul nearly twice as much as an ordinary locomotive of equal weight and power, and at the same or greater speed. Derailment is impossible owing to the horizontal wheels running along the sides of the centre rail, the latter being held as if in a vice, while the braking system adopted—either manually or automatically operated—serves to hold the locomotive so steady and tightly upon the track that the latter must be torn up before the engine will leave it.

It has also been found, from actual experience, that with the centre-rail system there is much less friction on curves, and consequently reduced wear and tear on the tyres and flanges of the carrying wheels. The horizontal wheels take up the pressure due to centrifugal force, and keep the flanges from bearing and grinding against the outer rail. Another advantage of the idea is that guard rails are unnecessary because the horizontal wheels resist any climbing tendency on the part of the engine.

When Mr. Fell had perfected his idea he submitted it to some searching tests upon a length of line which was laid down upon his principle on the High Peak of Derbyshire with banks running up to as much as 1 in 10. These trials convinced the inventor of the complete feasibility of the system. The difficulty was to persuade railway engineers of its advantages—no easy matter in those days when railway

engineering knowledge was somewhat scanty.

An opportunity arose in 1863. The Cenis Tunnel was in progress, but there was a heavy and increasing traffic which had to be maintained as efficiently as possible by means of diligences over the Cenis Pass. This slow method affected commercial interests very adversely, since the mails suffered considerable delay. Accordingly, Mr. Fell suggested that he should build a railway upon his system over the mountains to handle the traffic while the tunnel was being bored.

It was a daring proposal, inasmuch as it involved the construction of a line 50 miles in length, extending from St.

Michel, the terminus of the **The Mont Cenis Line.**

Paris, Lyons and Mediterranean Railway, a climb to an altitude of 7,000 feet and then a descent to gain the Alta-Italia Railways at Susa. The two governments entertained the proposal sympathetically, but thought it an experiment, and so were somewhat dubious of its success, seeing that it differed completely from existing practice. However, they did not reject it, but suggested that the promoters should build a trial line among the mountains and run it during the winter months. It was about as supreme a test as could be conceived, but it was accepted. A trial line, $1\frac{1}{2}$ miles long, was laid down on the famous high-road zigzag known as Les Echelles, above Lanslebourg, at an altitude of 6,000 feet above sea level. On this section, owing to the contour of the mountain, a maximum grade of 1 in 12 had to be introduced, while the sharpest curve was of 132 feet radius. The road was tested very severely during the winter owing to the severity of the blizzards, and the following summer the inventor's claims were more than substantiated. Accordingly, the French Government sanctioned the extension of the line from the Italian frontier to St. Michel, in November, 1865, while the Italian Government gave a similar concession to

carry it through to Susa in the following month. But there was one proviso. The two nations, having sunk so much money in boring the tunnel, were resolved to suffer no competition from the overhead railway; it was to be abandoned upon the opening of the tunnel.

A gauge of 3 feet 7½ inches was selected for the railway, this being cheaper to construct than the standard gauge, although it involved changing cars at Susa and St. Michel. The surveys showed that the steepest banks would be 1 in 10 and the sharpest curves of 132 feet radius. The promoters of the enterprise were permitted to follow the high road, and, in fact, were allowed to take a part of the latter for their right of way, so long as sufficient width was left for the diligences and other traffic.

As might be expected, railway building in such an exposed, wild mountainous country was not free from excitement and disaster. The builders clung as tightly as possible to the famous road built by Napoleon over Mont Cenis, some 12½ miles north-west of the tunnel—the latter is wrongly named—and work was commenced in 1866. Good progress was made up to the end of the year, but unfortunately the winter was abnormally severe. Such a low temperature prevailed that even the earth-works had to be carried out by blasting, while the holes for the posts of the fencing had to be sunk by explosives. Spring brought its own peculiar troubles in the shape of terrible floods, avalanches, and rock-slides. About 1½ miles of the track were wiped out of existence, several bridges were smashed; in fact, work had to be suspended entirely on the French side. Yet, despite these calamities, the last rail was laid on August 15th, 1867, and eleven days later the first train steamed from St. Michel to Susa over Mont Cenis.

Further troubles now developed. The locomotives had to be built in France, and were found so defective that they had to be rebuilt practically, so that the line could

not be brought into service until June, 1868, on the fifteenth of which month the official inauguration took place amidst great rejoicings. The blind forces of Nature, as if infuriated at this human conquest, once more swept down, the floods washing away lengths of the line, breaking up the bridges, and wreaking devastation on every hand. Rock-slides were also of frequent occurrence, but the engineers overcame these visitations by throwing up massive masonry defences upon the mountain slopes above the line.

Although the railway from end to end was a wonder of engineering, the most imposing feature was the negotiation of the great Echelle.

Passage of the Echelle

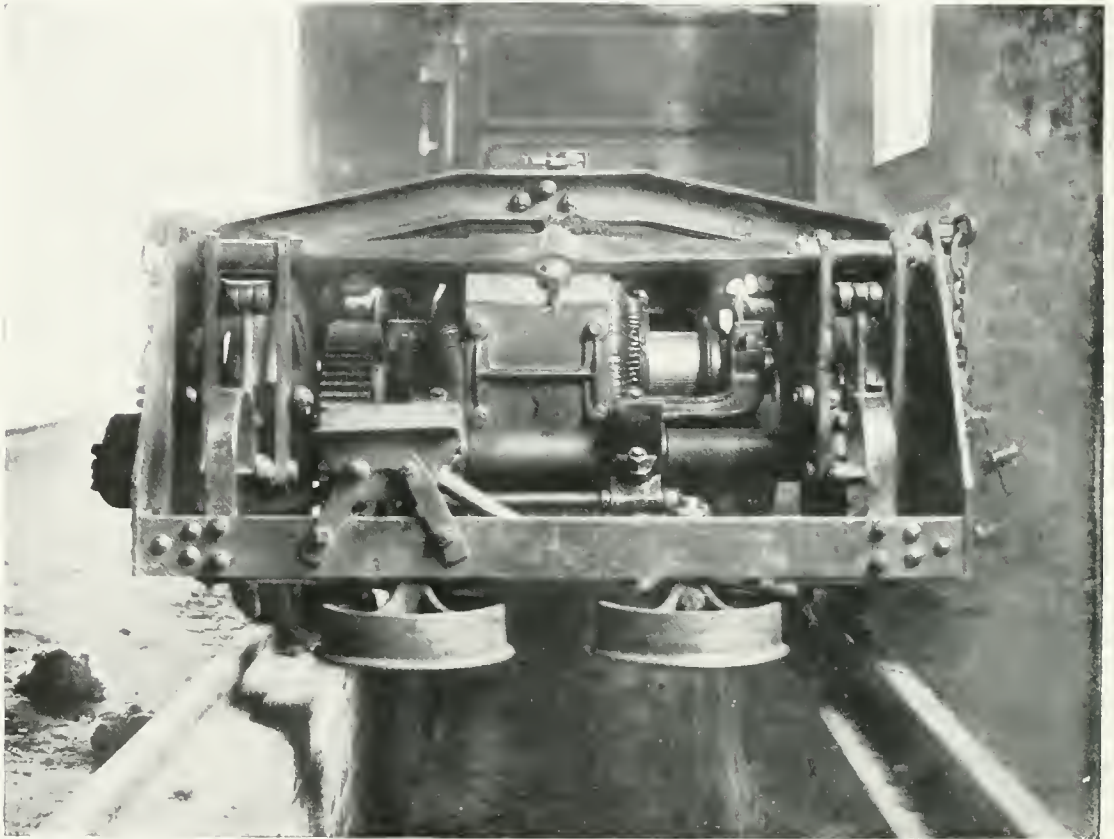
Here the high road saws the mountain in a wonderful zigzag cut out of the face of the cliff. The railway followed the high road, but was forced to take the outer edge, so that passengers in the carriages looked sheer down for 1,000 feet into the yawning guleh. As the track could not be zigzagged in the manner of the high road, a kind of elaborate spiral was laid out, the tunnels being driven through the spurs at the end of each incline, so that the ascent was made in the manner of a big corkscrew, one level being immediately above the other. The passage of the Echelle provided the greatest thrill in the whole journey, as at places the sides of the cars overhung the cliff.

For three years this unique railway handled the whole of the international traffic—mail, goods, and passenger. During this period over 150,000 passengers were carried without a single fatality, and there was only one minor accident to a goods train. One stormy night the driver, in descending the incline, reversed his engine without first applying his brakes. The train got out of hand and the vehicles piled up in the ravine below, but the engine stuck to the rails.

Although the journey over the 50 miles occupied from 4½ to 5½ hours—including

Customs examination at the frontier—the most outstanding feature was the reliability and punctuality of the service. Often the time which had been lost upon other parts of the various railways was more than made up on the Mont Cenis Fell section. The railway cost only £450,000 to build,

abandoned when the Cenis Tunnel was opened, the advantages of the system have received their due though tardy recognition. The growth of traffic between Italy and France has over-taxed the tunnel. Additional tracks have been suggested, but they would involve the driving of another big bore,



UNDERNEATH VIEW OF THE FELL ENGINE.
Showing the horizontal wheels which grip the centre-rail.

an extraordinarily small sum when the mountainous character of the country traversed and the difficulties encountered are borne in mind. When compared with the outlay upon the big tunnel, which cost £5,320,000 to complete—£2,000,000 in excess of the estimates—the economical working of the system is emphasised more emphatically still. For the latter sum alone, a railway of standard gauge complying in every respect with trunk line conditions might have been built on the Fell system.

Although the Fell railway had to be

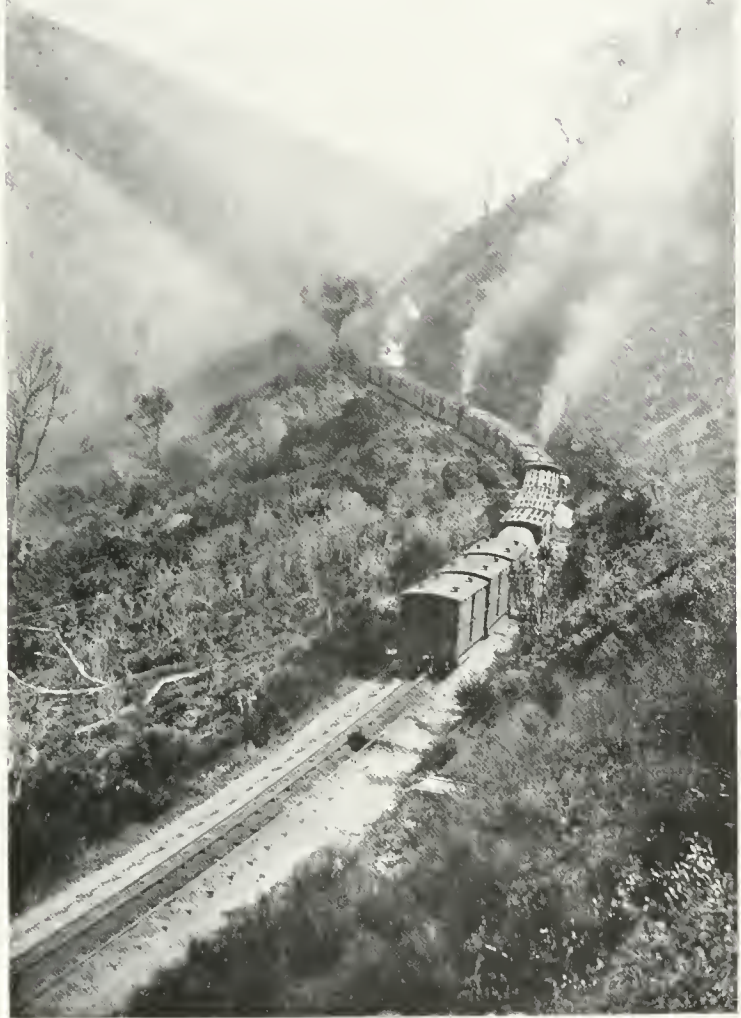
as the existing tunnel and its approaches cannot be widened except at prohibitive cost. Accordingly the resuscitation of the Fell system is being discussed as the cheapest solution of the difficulty. The original line, after its term of duty was fulfilled, was taken up and sold to one of the railways which now forms a part of the Leopoldina system in South America, where it was laid down to lift the railroad over the coast range, which rises very abruptly. There is no doubt that had Mr. Fell completed his original experiments before 1852 the Cenis

Tunnel never would have been built. Events have proved that it was a colossal mistake, due to the inability of the railway knowledge of the times to take the development of the steel-way into perspective. If the new Fell Railway is laid down it will be on the standard gauge, so that vehicles will be able to travel right through, engines only being changed at each end of the section, as is done even now to haul trains through the tunnel.

When the Wellington and Masterton Railway of New Zealand decided to extend its metals through the Rimutaka Pass, similar conditions to those prevailing in connection with Mont Cenis were presented. The railway engineers conceded that the only economical solution of the difficulty was to introduce the Fell Centre Rail through the Pass, where the banks run up to a maximum of 1 in 15 with curves of 330 feet radius. The traffic over this line is heavy, and it has been worked for over thirty years by Fell engines, weighing $41\frac{1}{2}$ tons in running order, having a tractive force of 19,400 pounds, and capable of hauling a load behind them of 70 tons up the maximum bank, at 10 miles an hour.

The system of working the traffic through this pass is interesting. As a rule the train is divided into sections, each having its own engine and all coupled together. In this manner each engine is caused to haul its own full load, and the couplings do

not have to withstand undue strains, such as would arise were a triple header and pusher system adopted. Thus it is by no means uncommon to see a train of twenty-eight vehicles, representing a dead load of



THE FELL CENTRE-RAIL IN NEW ZEALAND.

The train consists of 28 live-stock cars, weighing 260 tons, and is being drawn through the Rimutaka Pass. Each engine hauls 7 cars. The rise is 1 in 15 with several curves of 330 feet radius.

260 tons, with the locomotives disposed throughout the train, so that each hauls seven vehicles, ascending the incline, for which duty a period of forty minutes is allowed.

Some idea of the work which these engines accomplish may be gathered from



THE SNAEFELL MOUNTAIN TRAMWAY, ISLE OF MAN.

This is the only example of the Fell Centre-Rail System in Great Britain.

the fact that some 60,000 tons are put through this pass every year, and the average expense per locomotive is 5s. 10d. per train-mile, which represents about one penny per ton-mile. It is a moot point whether any other system could show such a low working cost under such conditions.

One accident happened upon this railway which emphasised the safety of the system very strikingly. During 1880 a violent storm raged, and in a very exposed part of the track the wind literally blew the train off the metals. A Fell engine was hauling, and another banking up the incline, but the hurricane failed to move them from the track. This fact saved the whole train from disaster, as otherwise it would have been hurled down the mountain side; and although several passengers lost their lives, the calamity would have been far more terrible had the whole train gone overboard, as would have been the case

had there been no centre rail, which the engines, owing to the horizontal wheels and braking system, gripped as if in a vice.

There is one interesting example of the Fell system in Great Britain. This is in the Isle of Man, where a double tram-line climbs Snaefell from Laxey up a grade of 1 in 12. Each car has two pairs of horizontal wheels and ample braking power. One day a motor mishap brought an ascending car to a stop at a sharp curve, where the line overlooks a stream 100 feet below. A descending car on the other track stopped to extend assistance. Shortly afterwards a third car, also descending, rounded the curve at a high speed. Before the driver had time to apply his brakes he dashed into the stationary vehicle with such force that it was driven down the 1 in 12 bank. Owing to the system adopted, however, both vehicles kept the

rails, and reached the bottom safely, though somewhat damaged. Had there been no third rail the force of the collision certainly would have thrown both off the metals, in which event nothing could have prevented them making a bee-line into the valley below.

The advantages and possibilities of the Fell Centre-Rail System are recognised more fully to-day than when the Cenis line was carried out. The big tunnel fever has died down, as such undertakings are exceptionally costly, and in many cases unremunerative. In addition to the suggested double-tracking of the Mont Cenis route by this means, it is proposed to build another connection upon standard gauge trunk road principles through the Monginevra Pass, so as to offer a shorter and quicker route between Turin, Marseilles, the south, and east of France by way of Briançon and Oulx. This mountain railway will be laid on the Centre-Rail System over the Pass, the summit of which is 6,061 feet above the sea, and will be 25 miles in length. The passage of the mountain will occupy about two hours, and the cost of the line will be about £500,000. While the cost of working the line at this elevation will exceed that of operating a tunnel,

yet, if this latter charge is capitalised, and added to the cost of construction, the expenditure still will be less than one-half of that involved in driving a tunnel. Another important projected Fell line is that between Civita Vecchia and Terni, in Italy. At the present time, in order to pass between these two points, it is necessary to make a long detour via Rome, which is a severe handicap to the industrial and commercial expansion of Terni. A more direct route to the sea is in urgent request, but it is impracticable with an ordinary locomotive line, owing to the heavy ascent that has to be made from the coast. By means of the Fell railway it will be possible to follow almost an air-line from the seaboard to Orte, where the present main line can be rejoined for Terni.

That a method of railway transportation which had established its possibilities, and then had been permitted to lie dormant practically for thirty years, should undergo revival is somewhat unique in railway engineering annals. But it serves to emphasise how hard-pushed the railways are to-day in the struggle to make ends meet. Whereas half a century ago the idea was regarded somewhat as a novelty, to-day it has to be considered in the light of a necessity.



A COACH ON THE SNAEFELL MOUNTAIN TRAMWAY



ONE OF THE ELECTRIC GIANTS WHICH "WORKS" THE ST. CLAIR TUNNEL
These locomotives are of 2,000 horse-power, and weigh 135 tons

The Opening-Up of Canada—II

HOW THE ST. CLAIR RIVER WAS TUNNELLED AND NIAGARA BRIDGED



UNFORTUNATELY, for several years the international trade suffered from physical interruptions owing to the lakes and rivers forming Ontario's southern boundary. One of the most harassing of these was the St. Clair River on the main line between Chicago and Montreal. The trains had to be brought up to one bank, pushed on to steam ferries, transported intact across the river, and landed on the opposite bank to resume their journey. The delays, from ice in

winter and heavy marine traffic on this narrow neck of water during the summer, rendered some easier link between the two nations imperative.

A bridge was out of the question, so in 1886 it was decided to lay a single-track tube beneath the water, between Sarnia on the Canadian shore and Port Huron on the American bank. Mr. Joseph Hobson, who was chief engineer to the undertaking, completed the work without incident by recourse to the Greathead shield, whereby the London tube railways were rendered

possible. The St. Clair Tunnel is 19 feet 10 inches in diameter, and is lined throughout with cast-iron segments representing 25,000 tons. From end to end it measures 6,932 feet, with long steep approaches on either side, owing to the flatness of the country, and cost £540,000.

The tunnel was brought into service in September, 1891, and the advantages over the ferry were instantly apparent. But there was one serious disadvantage: the trains hauled by steam locomotives choked the tube, so that after one had passed some time had to be allowed to permit the bore to clear itself somewhat. This practice brought about such serious delays that it seemed as if another tube would have to be built, unless the capacity of the original tunnel could be improved. The weight of

the steam-drawn trains could not be increased with safety. The engines used were the largest then in existence, but, despite their power, they could not handle more than 760 tons, and on the up grades the progress was very slow.

Why not electrify the tunnel? The query was raised but the project seemed so stupendous at the time that there was justifiable hesitation as to its feasibility. Still, such a panacea was worth trying. There would be no danger from smoke and fumes; more trains could be passed through in a given time. The project was handed over to Mr. Bion Arnold, an accomplished electrical engineer, to thresh out. It demanded most searching investigation. However, Mr. Bion Arnold at last evolved a practical scheme whereby the weight of



THE ST. CLAIR TUNNEL.

An iron tube 19 feet 10 inches in diameter, through which passes all the main line international traffic, under the St. Clair River.

the trains might be increased to 1,000 tons, and capable of passing through the tunnel in 15 minutes with a maximum speed of 25 and a minimum speed of 10 miles per hour. The time occupied in transit includes movements at each end of the electrical section, which would not be entailed were the whole railway worked electrically.

The contract was sanctioned, and fulfilled by the Westinghouse Company at a cost of £100,000. The locomotives, weighing 135 tons, and developing 2,000 horsepower, are among the heaviest in the world engaged in such work. Although their introduction accelerated movement

through the tunnel, and eased the traffic situation very appreciably, the growth of business is increasing at such a rapid rate that the laying of a second tube cannot be delayed many years. As it is, the St. Clair Tunnel is one of the busiest two miles of main line in the world.

The number of links which the Grand Trunk Railway has forged between Canada and the United States is a conspicuous feature of its energetic operations. In the 'fifties it became necessary to connect the State of New York with Ontario. But the Niagara River and rapids thundered through a gorge separating the two

countries. Mr. John A. Roebling threw a suspension bridge across the chasm, carrying a single pair of rails on the upper, and a roadway on the lower, deck. It was a striking piece of work, 821 feet 4 inches in length between the towers, carried by four cables each 10 inches in diameter, and was completed for £80,000.

But the old, old story came to be repeated. The bridge, adequate for the traffic of 1855, when it was opened, was totally insufficient for the business of forty years later. When the suspension bridge



BUILDING THE SINGLE-SPAN STEEL ARCH BRIDGE AROUND THE OLD SUSPENSION BRIDGE ACROSS NIAGARA'S GORGE.



Photograph by permission of the Grand Trunk Railway.

THE GRAND TRUNK SINGLE-ARCH DOUBLE-TRACK STEEL BRIDGE OVER NIAGARA GORGE.
There is a public highway below the railway deck. Length from end to end 780 feet, span 500 feet. The railway metals are 226 feet above the river.

was built locomotives exceeding 35 tons in weight were unknown, while a train of 200 tons was quite a rarity.

Accordingly a new structure was proposed. This assumed the form of a single

the traffic and the old suspension bridge was demolished. Although the exigencies of commerce brought about the supersession of one of the most famous suspension bridges in the world, its successor compels



VIEW OF THE NIAGARA SPAN BRIDGE AFTER THE REMOVAL OF THE SUSPENSION BRIDGE.
Showing top railway deck and lower deck for public use.

steel arch, 550 feet clear in the span, springing from the cliff face on either side, the two railway tracks being laid on the top, and the pedestrian and vehicular traffic having the lower deck as before. On each side the central span is reached over a shore span, bringing the total length of the bridge to 780 feet, with the metals 226 feet above the water.

The new bridge was built around the old one, so as not to interfere with traffic, and 3,600 tons of steel were worked into position. When the new structure was completed at a cost of £100,000 it took up

equal attention as being one of the largest single-span steel arched bridges ever built. The graceful festoon of the chains cleaving the air has been replaced by the equally graceful upward springings of the arch.

When the railway was first opened the engines and rolling stock were brought from England. Among these locomotives the "Birkenheads," so named after their town of origin on the Mersey, achieved deserving fame. They were of the broad gauge with outside cylinders. When the gauge was changed some of these engines were converted, while others were sold.

Wood was used as fuel in the earlier days, the tender being piled up with baulks, such as are used for stoking steamers on the back-wood waters of Canada to this day. Wood was cheap and plentiful in close proximity to the railway; coal was expensive and somewhat difficult to obtain. The rural population plied a thriving industry supplying the railways with cordwood, ramparts of which were piled up on the banks overlooking the line, to be measured and taken periodically to the depots by the wood trains; or the engines stopped on their journey and "bunkered" alongside a friendly cordwood pile. The railway assisted the settlers very tangibly in this direction; timber was anathema to the pioneers, as huge stacks accumulated in clearing the land for farming. The railway by purchasing the commodity in large quantities offered the settlers some compensation for their labours; while the sweat of their brow was not so wasted as it is to-day, when the scrub is piled in huge heaps and burned to waste.

Many amusing incidents are related of those old cordwood days, and railway travelling certainly possessed an air of novelty which was not encountered in Britain.

The Old Cordwood Days.

Occasionally a train would break down miles from anywhere. The driver and fireman would set to work and repair the mishap sufficiently to enable them to crawl home. But while they were at work, and the passengers were amusing themselves scouring adjacent woods for excitement or killing time in conversation with neighbouring isolated settlers the engine was eating up quickly its bunker of wood. Con-

sequently when all was ready to re-start "wooding-up" became urgent. In this task the passengers were forced to assist. If a cordwood pile were convenient the job was not particularly arduous, although packing cordwood over even a hundred yards is not child's play, as I have found from experience. But if there were no available supplies, then the driver and his mate passed axes round, and one and all had to set to bringing down the trees and splitting them up for the engine. It was useless to complain or to try to shirk the compulsory unpaid duty. If the passengers demurred, the driver and firemen wasted no words, but took a nap until such time as the travellers, thinking better of their objections, sullenly submitted to the ordeal.

Although the financiers and railway builders who set out to open up the silent timber fastnesses of Canada some sixty years ago did not reap the reward they deserved, yet at the same time they completed a task which even now is scarcely appreciated. The Fathers of the Grand Trunk not only laid the foundations of a large and flourishing railway network, but they brought vast stretches of forbidding wilderness under cultivation and settlement, attracted people to the country, and paved the way for the realisation of the Confederation of the Provinces. The Grand Trunk has been the pioneer of Canada throughout its existence. Even to-day it is pursuing the policy which was laid down sixty years ago, by bringing further raw chunks of wilderness into development, in the hinterlands of Ontario and Quebec as well as the North-West.

**Position
of the
Grand Trunk.**



THE MAKING OF THE UGANDA RAILWAY: READY FOR THE RAILS.
A bridge completed and the grade finished to foundation level.

Threading the Great Natural Zoo—I

THE WONDERFUL STORY OF THE UGANDA RAILWAY

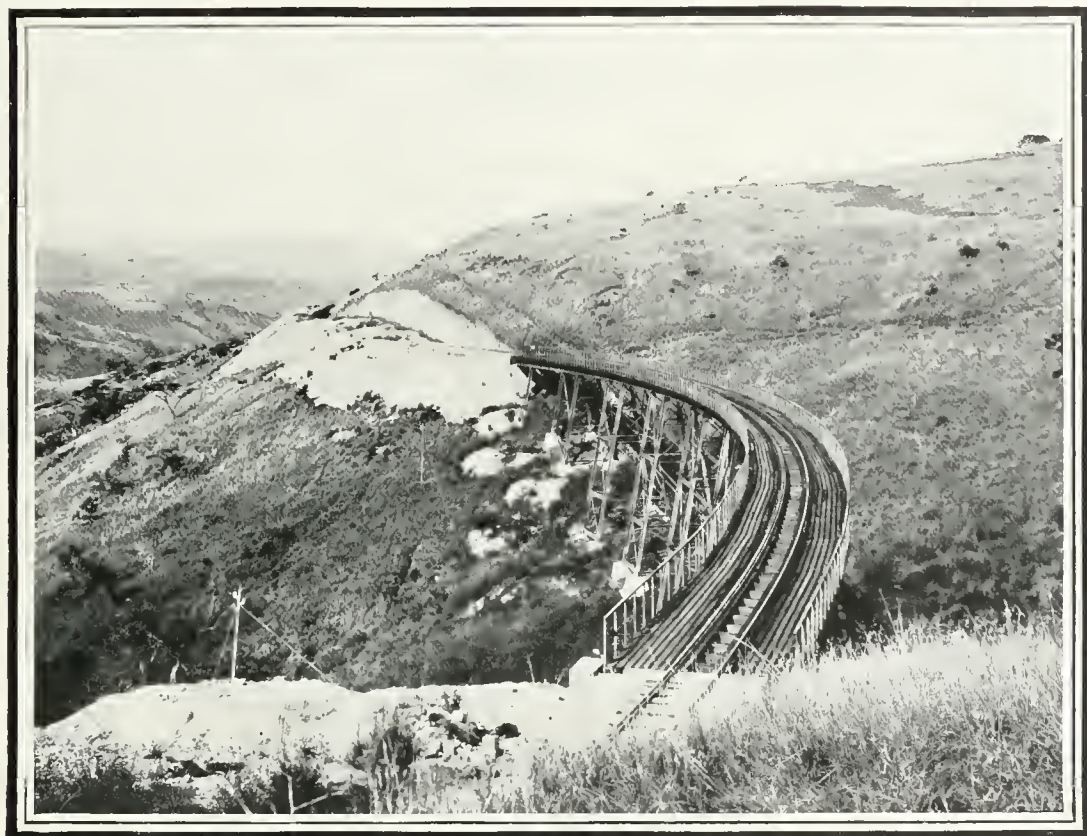


TWENTY-FIVE years ago, if one animated by the wanderlust essayed to cross the Dark Continent to the Victoria Nyanza he experienced adventure, sensation, thrills and excitement in plenty during a tramp of nearly 700 miles. One not only had to be a walking arsenal, but required an armed escort as well, for once the coast was left behind a "shooting iron" was as essential as a compass. The interior was not only thickly infested with dangerous big game of all descrip-

tions, but the various native races, such as they were, displayed a more keenly developed preference for the arts of war than of peace. In addition, the Arab slave raiders found the country a rich field for the pursuit of their nefarious calling. Under these conditions the unexpected was likely to happen at any moment. The loads carried on their heads by the native porters were apt to be discarded suddenly to permit the frightened packers either to shin a tree out of the way of a lion, or to bolt into the bush from one of their implacable enemies. If the train were kept

intact there were the risks of becoming stranded upon the waterless desert to suffer the pangs of thirst, while dependence, to a very pronounced degree, had to be placed upon Nature's larder for the necessities of life.

ing 89,500 square miles, until a railway was built. But to drive a steelway through a new territory for some 600 miles, which was incapable of extending the slightest support, where there were no roads, with the markets thousands of miles distant and



A TYPICAL VIEW UPON THE UP-COUNTRY SECTIONS OF THE UGANDA RAILWAY.
Owing to the rolling nature of the country extensive bridging and heavy cuttings were required.

But to-day one can pass from the seaboard to the waters of the remote interior in the luxury and comfort of the African equivalent of a Pullman car. The days of internecine warfare are over; the slave raider is but a memory; the only remnant of the exciting times of a generation ago is the game, which still is found in plenty.

The subjugation of British East Africa, more generally known as Uganda, was completed through the initiative of the British Government. It was realised from the first that little could be accomplished with this slice of the continent, aggregat-

labour non-existent, was not to be undertaken lightly. It could be consummated only in one of two ways—by official assistance in the form of heavy constructional subsidies, or by the Government itself. A careful review of the situation proved the latter to be the only solution of the problem.

Accordingly, in 1893, a survey party was dispatched from the coast to make the preliminaries. The expedition was exciting and full of adventure. In the innermost stretches of the country the party encountered a certain amount of native

hostility, and had their tussles with the wild denizens of the forest, as well as suffering the trials and tribulations incidental to the crossing of a waterless country. In due time they came back with a feasible location, but pointed out that everything was dead against the engineer, owing to the broken character of the country to be traversed, the necessity to introduce steep banks and sharp curves, and the difficulties that would arise from feeding those on the grade.

But the British Government was resolved to build the line at all hazards.

It was estimated that the provision of the railway would involve an expenditure of about £3,000,000. This figure was based upon that of other British-built African railways of metre gauge, which was that selected for this line, and which was to be nearly 700 miles in length. In fact, one private firm of contractors offered to complete the undertaking for £2,500,000, provided they were given wide discretionary powers concerning gradients and curvature. This proposal, however, did not meet with official approval, and the authorities decided to complete the work by direct labour.

Mombasa was selected as the constructional base, the line being pushed inland from the seaboard. The remote distance of the markets from the constructional site proved a heavy handicap, because supreme difficulty was experienced in maintaining a steady supply of stores and materials.

The labour problem was more acute. The natives knew nothing about work according to the white man's interpretation. Whatever skilled labour was required had to be imported, mostly from India, and these men did not take long to realise, after their arrival, that they controlled the situation. Now and again the steadiness of toiling was rudely unset by small sec-

tional strikes or attempts to take advantage of local conditions: but the threat to send the malecontents home generally sufficed to quell striking tactics, while attempts at hoodwinking the "boss" by loitering over the work did not meet with much success, as these efforts generally were met with the introduction of piecework rates.

The natives' way of doing things, too, often was a source of amusement and procrastination. They knew nothing about wheel-barrows, picks, steam-diggers, cranes, and other pieces of heavy artillery usually adopted by the railway builder. The basket was their favoured means of transport, and they used their heads instead of their backs for carrying purposes. Shifting a hundred pounds or so of earth at a time in this manner strikes the highly drilled scientific railway builder as distinctly primitive, but it is a condition of affairs which has to be tolerated.

One of the engineers who went out to Uganda from the United States to assist in the erection of the viaducts, and who met the African natives at close quarters for the first time, was highly amused, and laughed long and loud at the primitive practices adopted: but he altered his opinion in the course of a few days. "Why, an embankment was like an ant-hill," he confessed to me. "Those natives swarmed in two continuous streams—one coming with loaded baskets from the cut, and the other going empty from the dump. They kept it up for hour after hour, and I guess that by the end of the day they had done more work than a dozen steam shovels and muck-trains. Why, hydraulic sluicing could not shift the spoil in heavier streams than did those niggers with their head-baskets."

Owing to the coast terminus being at Mombasa, the first big work was the crossing of the channel to gain the mainland. For constructional purposes a timber trestle

**How the
Natives
Worked.**

**Estimated
Cost.**

**Labour
Difficulties.**



THE FOE OF THE RAILWAY-BUILDER IN CENTRAL AFRICA

During the making of the Uganda Railway the construction camps were raided frequently by lions, and at one time their persistent attacks stopped the work completely.

was laid down, the erection of the viaduct known as the Salisbury Bridge, 1,700 feet in length, being carried out at leisure. This bridge is of the trough type and supported on steel bents. The plate girders were riveted up on stages on the Mombasa shore and floated out to position between the piers on pontoons, and then hoisted into place.

From the seaboard the land rises brokenly and suddenly 530 feet in the first 16 miles. To overcome this difference in elevation a grade of 1 in 50 was found to be unavoidable. The country is thickly covered with jungle, these conditions prevailing as far as Maji Ya Chumvi, 35 miles inland, at an altitude of 570 feet. This is virtually the limit of the coastal belt, because from this point to Maungu, at mile 85, stretches what is known as the Taru desert, an evil country covered with a thick, thorny scrub. Even natives and animals appear to dread this almost waterless, depressing tract, because it offers few evidences of being favoured by man or beast. Driving the steelway through this scrub, which presented a forbidding aspect, harassed the engineers sorely. Its evil reputation—for it was here that formerly many expeditions came to grief—seared the workmen. They could not overcome the dread that water would run out and leave them stranded to suffer the pangs of thirst. The builders placed capacious cisterns upon flat deck trucks, and established a regular water train service, because nearly every ounce had to be brought up 30 miles or so from the rear. In crossing this desert the railway makes a continuous climb of 1,130 feet in the course of 50 miles. On reaching Maungu, however, the physical characteristics change suddenly, the desert giving way to more inviting though heavily undulating country.

Although railway construction was carried out with supreme difficulty through

this stretch, the first serious balk came when the Tsavo River was reached near mile 133. The waterway is not very impressive, though it has cut a channel between two lofty banks, while the bridge is not a big one as bridges go. It comprises four spans, each of 60 feet, carried on three substantial stone piers. The bridge is of the plate girder top-deck type, and, owing to the absence of the facilities generally available for such work, the setting of the steel had to be carried out on quite novel lines. The engineer in charge, Lieut.-Colonel J. H. Patterson, built up a temporary tower or crib with railway sleepers between the abutment and the first pier. From the top of this he laid heavy timber balks extending to the abutment and to the pier respectively. On these he laid a temporary track. Meanwhile, the plate girder span had been riveted up on the bank behind, and when complete was placed on railway trucks. The load was then carefully pushed over the gap spanned by the great balks, until it came dead into position between the pier and the abutment. Then the span of steel was jacked up off the trucks, so that the latter could be withdrawn from underneath. The jacks were then lowered until the steel came to rest upon the masonry, the timber balks and top of the crib work being lowered to allow it to be set. Each span was undertaken in this manner, and although the bridge occupied longer time in its erection than would have been the case had cranes or even a derrick been at the engineer's disposal, the task was completed successfully and relatively cheaply.

But it was not the setting of the steel which occasioned the delay, nor scarcity of labour, but a far more formidable foe. A large camp had been formed on the east side of the river, and work was proceeding quite uneventfully when a number of man-eating lions appeared upon the scene.

Lions in
the Path.

They raided the camp, picked up sleeping natives, and bore them away into the forest. Elaborate precautions and ingenious defences were thrown up to ward off the hostile inhabitants of the bush, but to no avail. These lions were among the most cunning that ever threatened an

stiff and as unequal a combat as ever man attempted. His subjugation of the man-eating lions constitutes one of the finest stories in the history of big-game hunting, and he has related his endeavours and successes in a wonderfully thrilling volume, "The Man-Eaters of Tsavo."



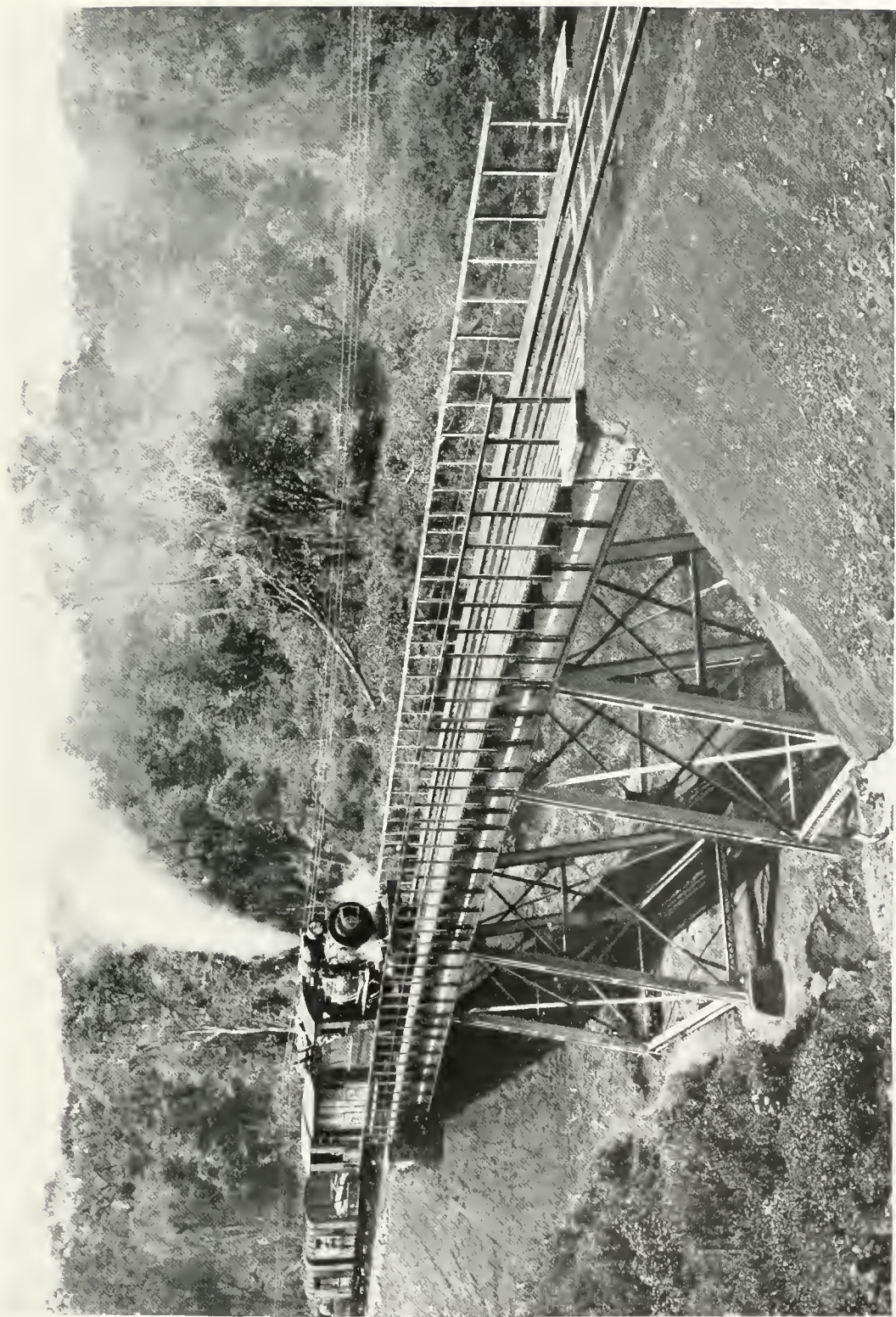
A STEEL TRESTLE BRIDGE ON THE UGANDA RAILWAY.

encampment. The labourers, unable to thwart the machinations of the beasts, grew alarmed, and resolutely refused to stay in the accursed spot unless an impenetrable and unscalable iron fence were thrown round their precincts.

Through the lions construction was brought to a standstill, and the ill-fame attached to the neighbourhood of the Tsavo River became noised so far and wide that no man would volunteer to go to the bridge unless the lions were exterminated. Lieut.-Colonel Patterson essayed the task of fighting the animals, but it proved as

Although he finally succeeded in ridding the country of this terror and restored confidence in the minds of his workmen, it was not before the voracious creatures had devoured twenty-nine Indian workmen and no one knows how many natives.

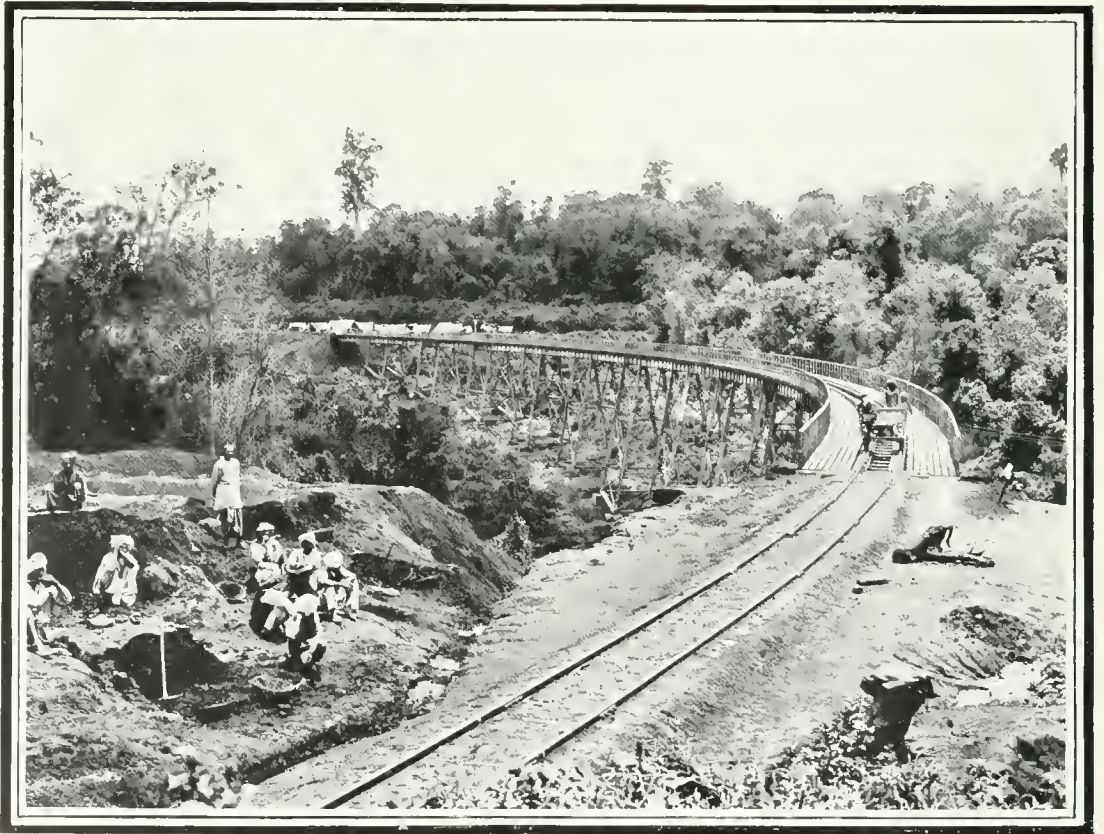
Still climbing, with grades ranging from 1 in 100 to 1 in 66 and 1 in 50, making sweeping curves, striking across deep rifts and through deep cuttings hewn out of massive shoulders, and describing big loops a mile or more in length to ascend a few feet, through rolling and open country and



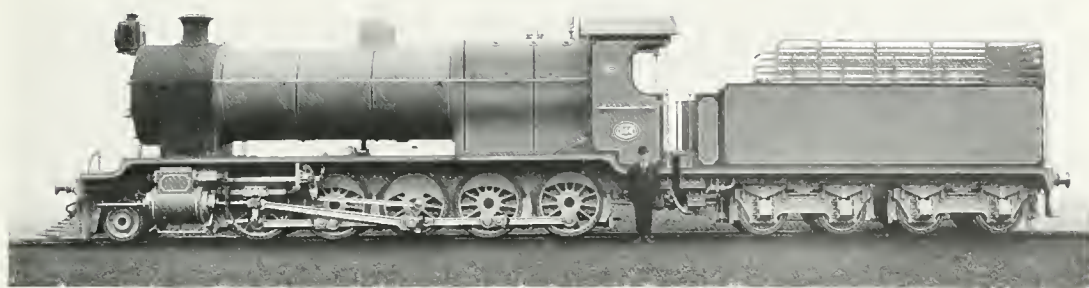
A GLIMPSE OF THE UGANDA JUNGLE PENETRATED BY THE RAILWAY.
The embankment approaches to the steel bridge were built up by natives, who carried the "spoil" in head-baskets.

dense jungle, the railway reaches Nairobi 327 miles out of Mombasa, and 5,450 feet above the sea level. Here the climate is delightful, cool, and even bracing. As this is practically the half-way house between the coast and the inland lake terminus of the railway, while its situation is so attractive and congenial to the white men, it was selected as the head-quarters of the railway. There is a well-built station, replete with every convenience, commodious yards, stores, engine sheds, and workshops. Incidentally one is given a compelling and intimate illustration of the vast changes that have been wrought by the railway during a single decade. In the shops may be seen African natives who, less than ten years ago, lived by war or herding cattle with only beads and fearsome colour-smears on their bodies as clothing, now engaged in wielding hammers, blowing forges, and working with machine tools to build

engines and other rolling stock, as well as fashioning the thousand and one other articles demanded by a big and important railway. The rapid and thorough conversion of the natives within such a short space of time offers one of the most convincing instances of the power and capacity of the British in colonising. On all sides of the station, as far as the eye can reach, are evidences of enterprise and industry. The virgin belt has been reclaimed and converted into farms. Large herds of cattle roam the rolling grass-land, recalling the huge ranches which were so plentiful in North America twenty years ago. Tall, rank grass has given way to cereals; the useless scrub has disappeared in favour of economically useful vegetation; the native has discarded his rude, primitive garb, and now stalks about in the white man's dress, somewhat bizarre and weird in its harmony perhaps, but civilised for all that.



A BRIDGE CONSTRUCTION CAMP ON THE UGANDA RAILWAY.



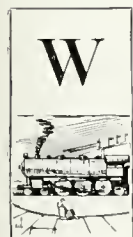
By permission of Messrs. Robert Stephenson & Co., Ltd., Darlington.

DECAPOD BUILT FOR THE ARGENTINE GREAT WESTERN RAILWAY.

The line is of 5 feet 6 inches gauge. In working order this locomotive weighs 135 tons complete.

Locomotive Giants—III

SOME CONTINENTAL AND AMERICAN MAMMOTHS COMPARED



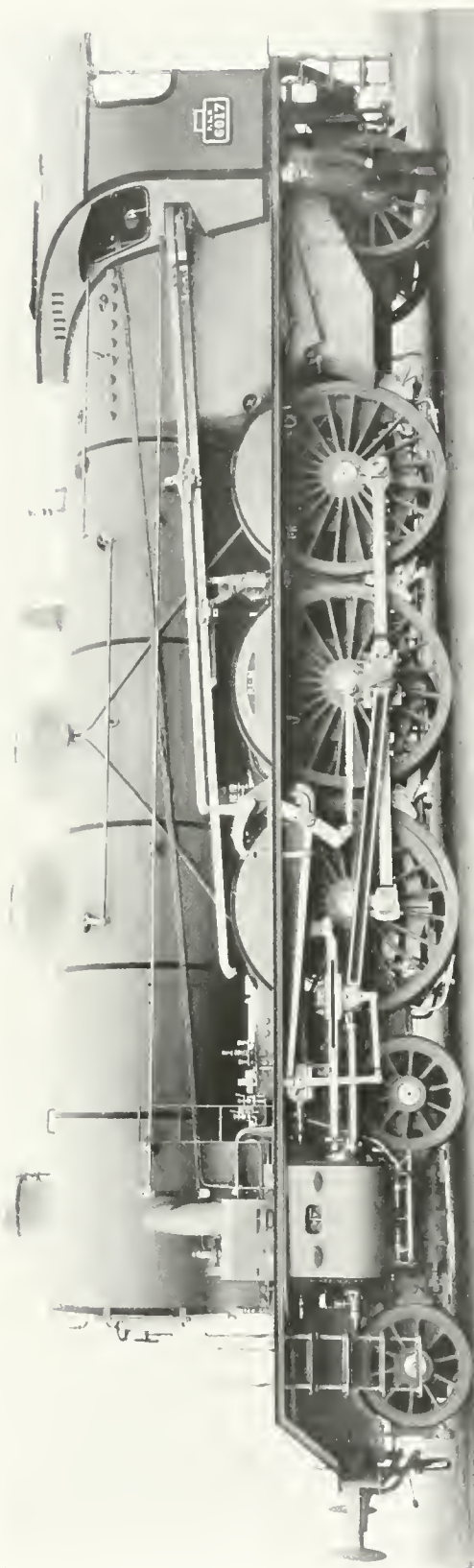
WHILE possibly the railways of these islands may not be able to produce many locomotives of huge dimensions, comparable with those found in other countries, yet at the same time British locomotive builders, who supply the railway requirements of the whole world, have constructed machines which have aroused attention from their size and character. Some time ago the pioneer locomotive building organisation of Robert Stephenson and Company, Limited, of Darlington, built a number of big Decapods for the 5 feet 6 inches gauge of the Argentine Great Western Railway.

These engines are of the 2-10-0 type, with a total length, over buffers, engine and tender, of 64 feet 10½ inches. The cylinders have a diameter of 19½ inches, with a stroke of 28 inches. The ten coupled wheels are 51 inches, and the front bogie wheels 30 inches in diameter. The fixed wheel base is 19 feet, and the total wheel base 27 feet 2 inches. Being built for a broad gauge system, the maxi-

mum width is 10 feet 3 inches, while the extreme height is 14 feet. The heating surface of the copper boiler tube is 2,246 square feet, and of the fire-box 194 square feet, representing a total heating surface of 2,440 square feet, while the grate area is 36 square feet. Steam is used at a pressure of 180 pounds per square inch. The Walschaert valve gear, with balance slide valves, is used.

The total weight of the engine is 79 tons 12 cwt., in running order, of which aggregate 71 tons 6 cwt. are available for adhesion, bringing the maximum load upon each of the five driving axles to 14 tons 11 cwt. The tender, carried upon two four-wheeled bogies, having a wheel base of 5 feet, with wheels 38 inches in diameter, has provision for 5,000 gallons of water, and space for 5 tons of coal or 450 cubic feet of wood; and in working order represents a weight of 55 tons 8 cwt. Thus the complete weight of the engine and tender ready for service is 135 tons.

The expresses of the Paris, Lyons, and Mediterranean system are well known, and in the working of this traffic several vary-



PACIFIC (4-6-2) ENGINE BUILT FOR THE EXPRESS SERVICE OF THE PARIS, LYONS, AND MEDITERRANEAN RAILWAY.
 This locomotive is capable of attaining $74\frac{1}{2}$ miles per hour in service.

ing Pacific (4-6-2) types, both compound and simple, using saturated or superheated steam, are employed. One of the most recent locomotives for this service is the four-cylinder compound superheated machine built by Messrs. Henschel and Sohn, of Cassel, Germany. The crack trains on this line often attain a speed of $74\frac{1}{2}$ miles per hour, and this locomotive was designed to fulfil such requirements.

The high-pressure cylinders have a diameter of 17.3 inches, while that of the low-pressure cylinders is 25.5 inches, the stroke in both cases being 25.5 inches. The two high-pressure cylinders are mounted outside and the two low-pressure inside the frame. All four cylinders are worked by separate distributions, by means of which the admission into the high-pressure cylinders can be increased to 80 per cent., whilst that of the low-pressure cylinders remains constant at 63 per cent.

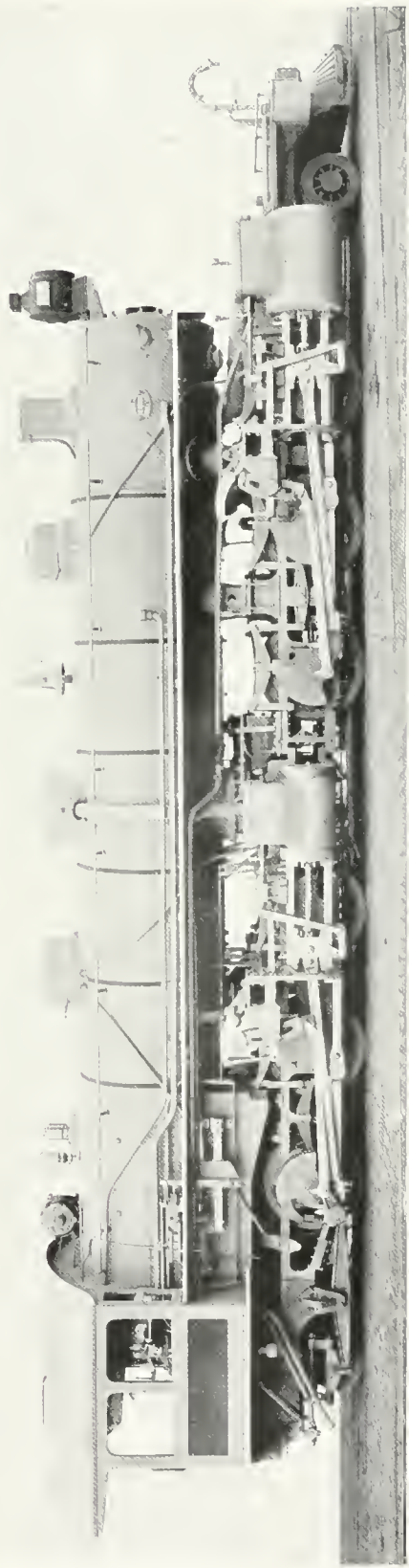
The driving-wheels have a diameter of 78.3 inches, while the diameter of the leading bogie wheels and of the trailing pair of wheels is $39\frac{1}{4}$ and $53\frac{1}{2}$ inches respectively. The 143 boiler tubes have an outside diameter of 2.16 inches, while the 28 fire-box tubes are of $5\frac{1}{4}$ inches diameter. The length of the boiler between the tube plates is 18 feet, while the diameter of the boiler in the centre is $66\frac{1}{2}$ inches. The heating surface of the boiler and fire-box tubes is 2,008.37 square feet, and of the fire-box 166.73 square feet, representing an aggregate heating surface of 2,175.1 square feet. The superheating surface is 694 square feet, and the grate area 45.76 square feet. Steam is used at a pressure of $227\frac{1}{2}$ pounds per square inch.

The over-all length of the frame, including the buffer, is 46 feet, and the total length of the wheel base 36.9 feet. The weight of the engine, empty, is 86.67 tons, the axle loads being distributed as follows: 10.4 tons for each of the two leading bogie axles, 18.07 tons upon each of the driving axles, and 15.46 upon the trailing axle, the total weight for adhesion thus being 54.21 tons. In working order the engine weighs 90.94 tons.

This same firm of German locomotive builders also has built lately an interesting double compound articulated Mallet for the Brazil Railway Company. This South American line is of the metre (3.28 feet) gauge, and notwithstanding the narrow gauge this engine is extremely powerful. Its object is not high speed, but rather the hauling of very heavy loads over a tortuous track abounding in stiff banks and very sharp curves.

The locomotive is of the 2-6-6-2 type with driving wheels 44.8 inches in diameter. The high-pressure cylinders, mounted on the rear frame, have a diameter of 16.9 inches, while the low-pressure cylinders carried upon the forward frame have a diameter of 25.9 inches, the stroke being 22 inches. The front is connected to the rear frame by means of articulated joint bolts. The distributions for all four cylinders are interlocked and regulated by a steam reversing gear on the Raggonnet system.

There are 194 boiler tubes of $2\frac{1}{4}$ inches external diameter. The boiler has a length of 21 feet between tube plates and a diameter, in centre, of 4 feet $11\frac{3}{4}$ inches. The boiler tubes have a heating surface of 2,371.3 square feet, while that of the fire-box is 154 square feet, the total heating surface thus being 2,525.3 square feet. The grate area is of 42 square feet. The working pressure of the steam is 200 pounds per square inch. The length of the engine frame, including cow-catcher, is 51.18 feet, while the total wheel base is 42.65 feet.



By permission of Messrs. Henschel & Sohn, Cassel.

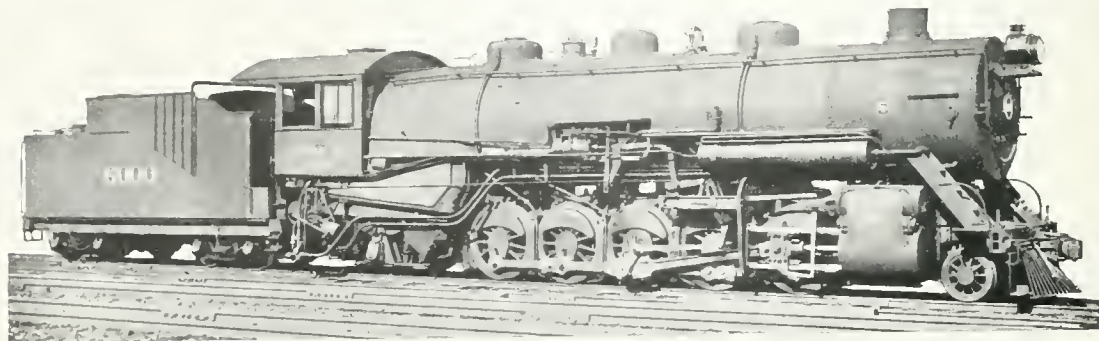
POWERFUL ARTICULATED (2-6-6-2) MALLETT DOUBLE COMPOUND BUILT FOR THE METRE GAUGE BRAZIL RAILWAY.
The engine weighs 87½ tons and can draw a train of 1,500 tons at a speed of 20 miles per hour round curves of 315 feet radius.

The weight of the engine in running order is $87\frac{1}{2}$ tons, the load distributed upon the driving axles being 12.27 tons, giving an aggregate of $73\frac{1}{2}$ tons for adhesion.

Increasing heavy traffic compelled the Chicago, Burlington, and Quincy Railroad to seek for more powerful locomotive effort to handle its heavy goods traffic, and, without embracing the Mallet system, this end has been fulfilled by the Baldwin

The tender, of the two 4-wheel bogie type, has a tank capacity of 10,000 gallons, and 15 tons of coal, and in running order weighs 91.65 tons. Thus the complete engine, ready for the road, turns the scale at 281 tons (American).

While the Pennsylvania Railroad Company has overhauled its system completely, eliminating all severe curvature and heavy banks, yet its freight traffic taxes the re-



THE MASSIVE BALDWIN (2-10-2) GOODS ENGINE BUILT FOR THE CHICAGO, BURLINGTON, AND QUINCY RAILROAD.

This locomotive complete for the road weighs 281 American tons.

Locomotive Company of Philadelphia. This firm supplied a 2-10-2 simple machine with cylinders of 30 inches diameter by 32 inches stroke. The boiler, of the straight type, is $88\frac{1}{2}$ inches in diameter, and works at a pressure of 175 pounds per square inch. There are 30 6-inch and 285 $2\frac{1}{4}$ -inch tubes, 22 feet $7\frac{1}{2}$ inches in length, having a heating surface of 4,841 square feet; while the fire-box, with 255 square feet, and the combustion chamber of 65 square feet, bring the aggregate heating surface to 5,161 square feet. The grate area is 88 square feet, and the Emerson superheater, with which the engine is equipped, has a superheating surface of 970 square feet (steam side). The outside driving wheels are 60 inches and the centre driving wheels 52 inches in diameter, the leading bogie wheels being 33 inches and the trailing wheels $42\frac{1}{2}$ inches in diameter respectively.

The total weight imposed upon the driving wheels is 150.9 tons, the complete weight of the engine being 189.35 tons.

sources of the operating department to a supreme degree. The fact that the system penetrates the heart of the Pennsylvania coal territory and serves the steel country affords some idea of the volume of the freight business which has to be handled. For the heaviest traffic of this character the railway has introduced some mammoth Mallet locomotives which, complete in running order, weigh no less than 334.45 tons.

These engines are of the 2-8-8-2 class with 56-inch drivers. The cylinders are 27 inches in diameter by 28 inches stroke. The round-top boiler has a minimum internal diameter of 86 inches, and has 282 tubes of $2\frac{1}{4}$, 45 of $5\frac{1}{2}$, and 180 of $1\frac{7}{8}$ inches external diameter respectively, by 23 feet $10\frac{7}{8}$ inches long between tube plates. The external heating surface of the tubes is 8,120.8 square feet, and of the fire-box 404 square feet, giving a total heating surface of 8,524.8 square feet. The grate area is 96.5 square feet. Steam is used at a pressure of 160 pounds per square inch.

In running order the engine weighs 241.35 (American) tons, the weights being distributed as follows: Truck, 11.25 tons; first pair of drivers, 26.75 tons; second pair of drivers, 27.5 tons; third pair of drivers, 28 tons; fourth pair of drivers, 26 tons; fifth pair of drivers, 26 tons; sixth pair of drivers, 26.5 tons; seventh pair of drivers, 31.75 tons; eighth pair of drivers, 26.75 tons; and trailing truck, 11.25 tons.

The length of the driving-wheel base is 15 feet 6 inches by 10 feet 10 inches by 15 feet 6 inches. The wheel base of the engine is 57 feet 5 inches, and the total wheel base of engine and tender 88 feet 2 inches. The tractive effort, with four-fifths of boiler pressure, is 93,312 pounds.

The Italian State Railways embrace some very heavy stretches of track, with severe gradients, particularly among the Apennines and the Alps. The goods traffic over these lines is somewhat heavy, and in order to cope with this movement the Societa Anomina Officine Meccaniche of Milan have built a powerful type of compound goods locomotive, the distinctive feature of which is the detachable tender. The first engine of this character was introduced upon the Italian State system about 1907 for working the passenger trains over the stiff Apennines section of the Rome-Florence-Milan line between Pistoja and Poretta. On this division the grade on the south side varies from 1 in 38.4 to 1 in 40 for a continuous 16 miles, and the task of operating the single track is aggravated by the curves, which range about 990 feet radius, and numerous tunnels.

The detachable tender was adopted because of the economies it offered in working. When running forwards the tender is in the conventional position, but instead of turning the engine round preparatory to the return trip, the tender is shunted and coupled to the chimney-end of the engine, thereby giving the driver a clear view of the track from his cab. Another novel

feature of this type of locomotive is the incorporation of a guard's compartment with the tender, so that it is not necessary to have a brake van next to the engine when operating goods trains.

The engine is a four-cylinder compound with ten coupled wheels (0-10-0 type) with drive on the third axle. The cylinders are so disposed that the two high-pressure cylinders are upon the right hand and the two low-pressure cylinders upon the left-hand side. In order to facilitate the rounding of sharp curves the first and fifth axles have a lateral play of about $1\frac{1}{2}$ inch, while the wheels of the main driving axle are flangeless. The low-pressure cylinders are 24 inches and the high-pressure cylinders $14\frac{3}{4}$ inches in diameter, with a common stroke of $25\frac{1}{2}$ inches. The boiler barrel is 22 feet 11 inches in length. There are 265 boiler tubes, giving a total heating surface of $2,416\frac{1}{2}$ square feet, while the heating surface of the fire-box is $123\frac{3}{4}$ square feet. Forward of the cab, and on top of the boiler, is the bunker for fuel, of 4 tons capacity. The total weight of the engine, ready for the road, is 75 tons, the whole of which is available for adhesion.

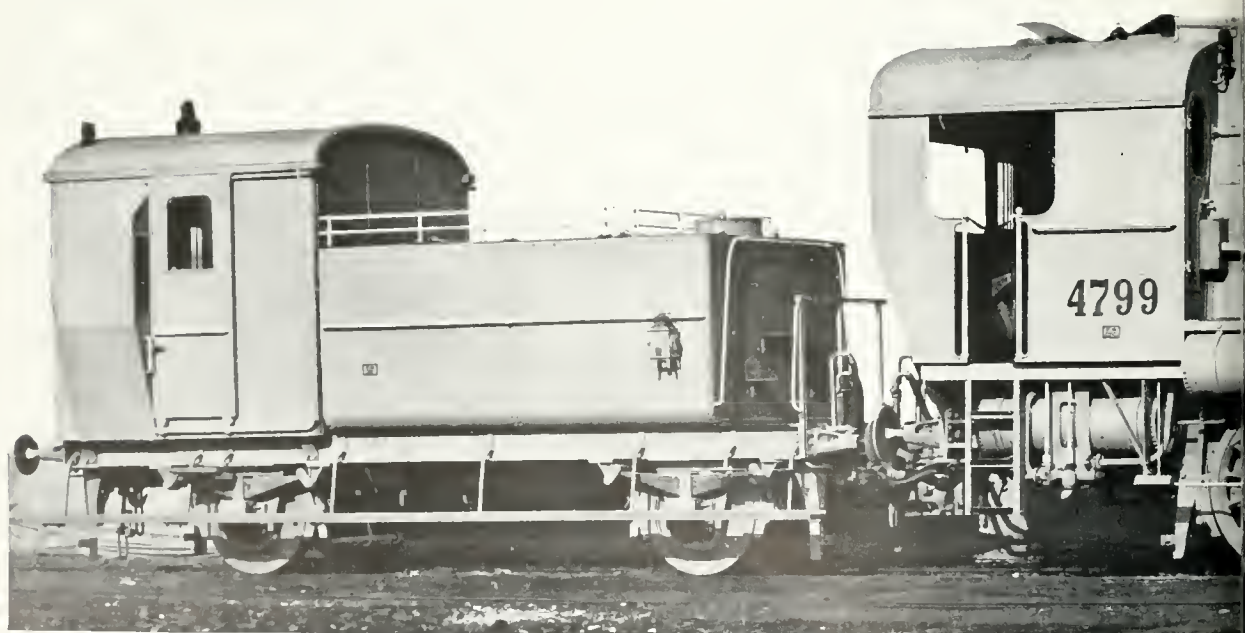
The four-wheeled tender, carrying water only, has sufficient space for 2,860 gallons. The total weight of the tender in running order is 26 tons, bringing the aggregate weight of the locomotive to 101 tons. The length of the tender is 26 feet 7 inches, which, added to that of the locomotive, 40 feet 11 inches, gives a complete over-all length of $67\frac{1}{2}$ feet.

The engines of this unusual type are restricted to the trying mountain division, and are among the most powerful in service upon the Italian State Railways. They have given complete satisfaction, not only on account of their hauling capacity but from their economical operation as well. They are able to haul a load of 270 tons, exclusive of the locomotive, up the 16 miles of the maximum grades at 20 miles an hour.

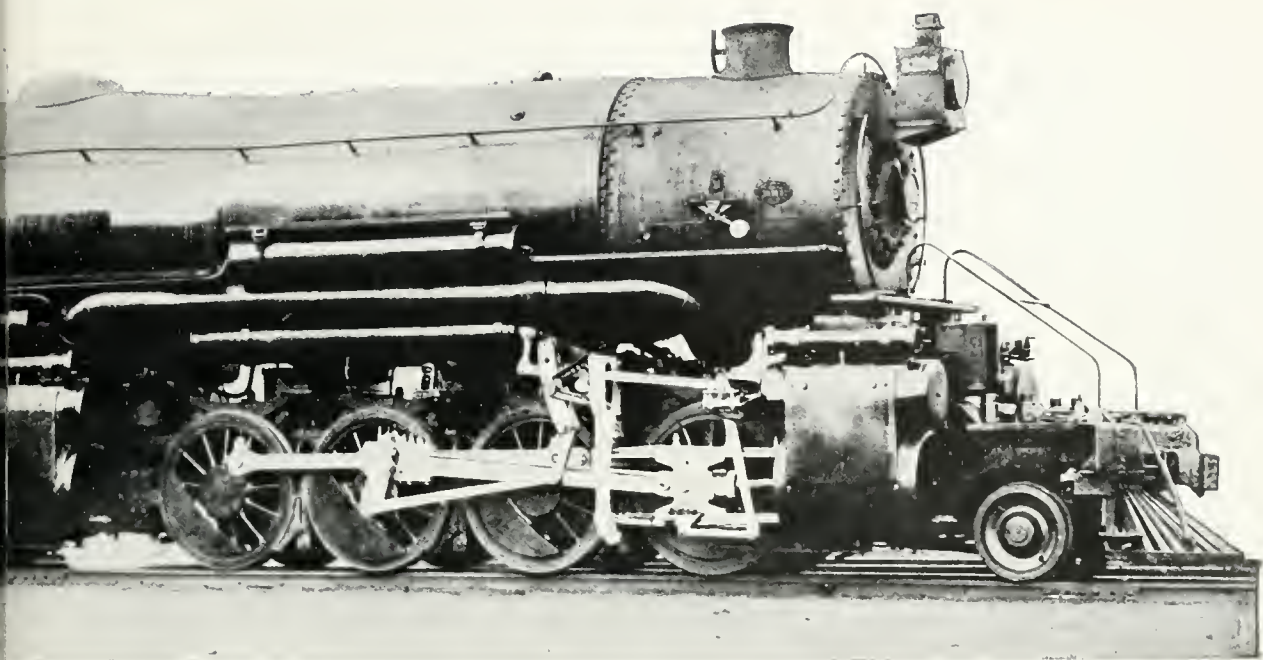
**The
Tender.**



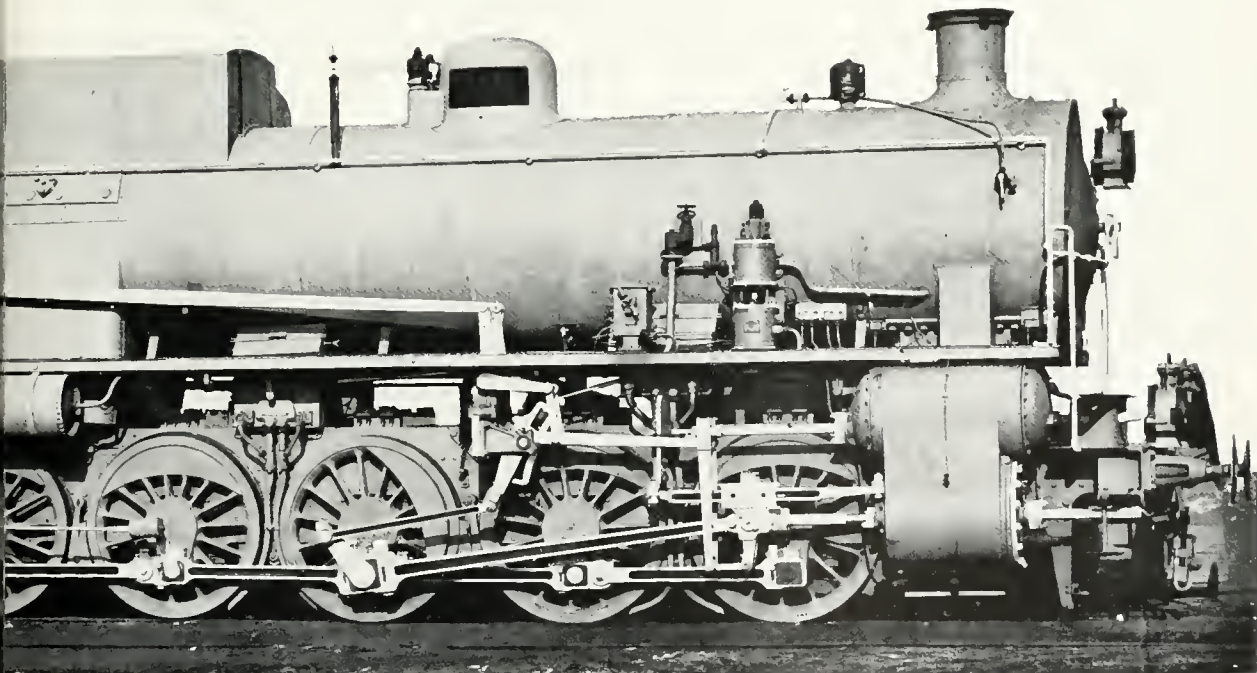
THE MAMMOTH MALLET ARTICULATED SIMPLE (2-8-8-2) LOCOMOTIVE USED
This engine has 56-inch drivers ; a total heating surface of 8,524.8 square



A NOVEL TYPE OF TEN-COUPLED BALANCED COMPOUND
This engine was designed expressly for mountain service among the Alps and Apennines, where continuous
can be attached either to the front or rear of the engine as desired. The coal



IN THE HEAVY FREIGHT SERVICE OF THE PENNSYLVANIA RAILROAD.
feet, and, ready for the road, weighs complete 334.45 (American) tons.



LOCOMOTIVE USED ON THE ITALIAN STATE RAILWAYS.
grades of 1 in 38.4 and 1 in 40 are encountered. The tender, carrying water only, and a brake compartment, bunker of 4 tons capacity is mounted on top of the boiler forward of the cab.



CUAUTLA STATION ON THE INTEROCEANIC RAILWAY, MEXICO.

The oldest railway station in the world. Built in 1657 as a convent, it was taken over by the Government in accordance with the Church Appropriation Order of 1856. It remained empty until 1881, when it was purchased by the Interoceanic Railway, and converted to its present use.

The Railway Development of Mexico

HOW THE NETWORK OF STEEL HAS BEEN WOVEN IN THE GREAT
CENTRAL AMERICAN REPUBLIC



THE country of Mexico always has been regarded as a kind of Tom Tiddler's Ground, possessed of dazzling attractions for the speculator. No one can dispute its vast mineral wealth, while its agricultural and forestal resources are every whit as important. Under these circumstances it is not surprising that enterprising individuals and companies sought concessions to construct railways for the exploitation of these varied riches of the country

The first railway was of very humble proportions, and, as usual, was due to British initiative. It comprised a small length of $2\frac{1}{2}$ miles, extending from Mexico City to Guadalupe. Other sporadic outbursts of railway-building activity were manifested during the following years, but progress was slow, and did not really follow any comprehensive scheme, being in reality odds and ends for the conveyance of products from one town to another. The first railway for general service was that completed in 1873 by British interests.

From this may be said to have sprung the present intricate network of lines, aggregating over 16,000 miles, serving the country.

Private enterprise received distinct encouragement during the 34 years' Presidency of General Porfirio Diaz. He recognised that his country was quite unable to help herself in the provision of railway facilities, and that she must depend upon outside sources to fulfil this end. Under his regime railway expansion went forward merrily, an average of 430 miles of new lines being built annually. He was the first to appreciate the wisdom of the policy of extending constructional guarantees, so as to induce the penetration and opening-up of new territories.

Under his sway, also, a new policy, which has exercised a far-reaching effect upon

the Mexican railway situation, was inaugurated. The Mexicans became somewhat distrustful of their northern neighbours. When the Speyer financial interests of New York organised the National Railroad Company as a successor to the Mexican National Railroad, and Harriman commenced to assert his dominating influence, a masterly stroke was played by the far-seeing Financial Minister, José Y Limantour, which effectively checkmated the aggressive and monopolistic tactics of the United States railroad kings. In 1903 the Mexican Government secured a controlling interest in the Inter-oceanic Railway of Mexico and the National Railroad; some years later a similar operation was carried out in regard to the Mexican Central and Mexican International Railways,



LAREDO BRIDGE, BETWEEN LAREDO, TEXAS, U.S.A., AND NUEVA LAREDO, MEXICO.

It comprises six spans each of 175 feet, with an approach at each end 65 feet in length.

and the whole consolidated, in 1908, under the name of the National Railways of Mexico. Since that date the important Vera Cruz and Isthmus and the Pan-American and Mexican Southern Railways have been brought in, and to-day the system comprises some 8,000 miles of main line extending from the Atlantic to the Pacific seaboard, and between the frontiers of the United States and Guatemala.

From the physical point of view Mexico is of a very diversified character. On the whole it is very mountainous, with towering ranges fissured by narrow yawning canyons. Consequently, when the engineers set out to thread the country, they were confronted with numerous teasing obstacles and in many places had to resort to ingenious construction, which demanded very close study and the exercise of quite original thought.

Take the Mexican Central, for instance, which runs from Ciudad Juarez to Mexico City, a distance of 1,224·3 miles. In putting this line through the plotters had to overcome three towering ranges, including the Sierra Madre. The metals had to be lifted from 3,723·4 feet at Juarez to 7,348·4 feet at Leña, and then had to descend to enter the capital. Yet the railway was built without a single tunnel. On the other hand, the engineers were forced to introduce curves of only 269·23 feet radius with maximum grades of 1 in 57, while numerous trestles were provided to span the deep rifts. The line was of standard gauge, was laid with 56-pound rails, and was completed in 1884.

Curves and Gradients.

About the same time the line from Chicalote, via San Luis Potosi, to the Mexican Gulf port of Tampico was constructed. On this line, in order to overcome a difference of 2,093·7 feet in 16·6 miles between Tamasopo and Las Canoas, the builders found it necessary to introduce banks as steep as 1 in 33·3 and curves as sharp as 259·38 feet radius. Owing to the

configuration of the country traversed, tunnel after tunnel had to be driven, and many of these bores, through stratified limestone rock, are upon curves of the minimum radius. The road was first laid with 56-pound rails, but, recently, in order to accommodate heavy Mallet locomotives and longer cars, 85-pound rails have been laid down. When this latter development in railway operation was taken in hand to cope with the increasing traffic, the tunnels had to be widened and lined.

The Mexican Central line was finished from Irapuato to Guadalajara in 1887-8, but during the years 1905-7

it was extended to Manzanillo, **The Mexican Central Railway.** on the Pacific Ocean, via Zapotlan and Colima through

the Rio Tuxpan Canyon, which extends along the base of the Colima Volcano. The work through this canyon proved heart-breaking, and was the heaviest per mile which has yet been accomplished in the Republic of Mexico, the earthwork between Tuxpan and Colima averaging 140,000 cubic yards per mile. The maximum grade was set down at 1 in 50, while the minimum curvature was placed at 501·5 feet. In order to get through the gulch heavy tunnelling became necessary, while the bridging is extensive also, owing to the numerous streams coming into the main canyon from the slopes of the volcano. Where the line swings from cliff to cliff across the ravine a bridge, 471 feet in length by 197 feet high, had to be introduced, while the barranca Santa Rosa is crossed at a point where the water is 279 feet below rail level.

The original line of the Cuernavaca and Pacific, which came under the control of the Mexican Central, represents an effort which was made to carry a railway direct from Mexico City to the Pacific Ocean seaboard. But it never got any farther than Balsas, a distance of 181·57 miles south of the capital. Between Mexico City and Cuernavaca the railway overcomes a differ-

ence of 2,549 feet in elevation, the grade being 1 in 33.3 to La Cima, and then descends on an identical grade to Cuernavaca. From the severity of the banks some idea of the rugged character of the country may be gathered, and the heavy grading is equalled by the sharpness of the curves—two adverse factors to economical operation. The extreme diffi-

from Puebla to Oaxaca was completed in 1889. While this railway is thoroughly well built its grade is one of the worst among the National lines. Leaving Puebla, where the rails are at an elevation of 7,056 feet, there is a slight fall followed by a rise for 12 miles on a bank of 1 in 55 to reach an elevation of 7,577 feet at Amozoc. Crossing this summit the fall is almost



CHOÑE RIVER BRIDGE

Photograph by C. E. Wente, Mexico.

The rail-base is 177 feet above the river level. The basaltic formation of the rock is curious.

culty which the railway builders experienced is revealed in the Canyon de la Mano below Puente de Ixtla. There was just the opportunity to get a railhold, and it was taken. The gulch is short, but its sides are vertical, and in places overhanging. The floor is occupied by the railway and the stream, and there was a severe dispute between the two for space. Fortunately the stream has shrunk, thereby leaving a narrow gallery available for the pair of metals, otherwise the line never could have been carried between the towering walls. As it was a maximum grade of 1 in 25 had to be introduced, with curves of only 330 feet radius.

The Mexican Southern Railway, extending

continuous, at 1 in 55, for 130 miles to Quiotepec, at an altitude of 1,804 feet. Then the line runs nearly level for a few miles, but with heavy curvature to Tomellin, crossing the two main streams forming the Papaloapam River. The excavation of a gallery out of the cliff face was abnormally heavy, while deflecting and retaining walls had to be introduced liberally. Travelling over this line offers a striking change in climatic conditions, and is trying to the passenger.

Leaving Tomellin the railway has a stiff climb to Las Sedas, 40 miles away, over a gradient of 1 in 25. The track is boxed in by the Sierras, the walls of which tower to a height varying from 1,000 to 2,000



NATIONAL RAILWAYS OF MEXICO'S MALLET ARTICULATED COMPOUND OIL-BURNING FREIGHT LOCOMOTIVE.

Total length 103 feet; weight in running order 227 tons.

feet. There was only one available location. That was alongside the stream, and the railway builders took it, following the latter's bewildering twists and turns slavishly until an elevation of 6,330 feet is attained. Yet the switchbacking upon a gigantic scale is not completed. The line has got to drop in order to gain Oaxaca at 5,084 feet, and the bank of 1 in 55 is taken up once more to achieve this end. It is fortunate for the passenger that this line runs through richly scenic and historic country, otherwise he would probably bemoan the slow pace of the train. In constructing this road it appears as if the engineers endeavoured to discover the most difficult instead of the easiest location.

When the old National Railroad from Corpus Christi, Texas, to Mexico City was undertaken, a narrow gauge was selected, as it was perfectly adequate for the existing traffic, but in 1902 it was realised that it would have to be converted to the standard gauge if it was to prove of service.

The whole line was taken in hand, 960 miles being rebuilt. It was a daring undertaking, because, at the time, the traffic had assumed considerable proportions. Yet conversion was completed in 18 months, and the task was carried out so skilfully that very few trains failed to maintain their scheduled times.

Reconstruction in itself proved a huge task. After leaving Celaya at 5,765.5 feet the line, by means of a grade of 1 in 50, and with curves of 247 feet radius, struggled to Toluca at 8,660 feet. From that point a still heavier rise—1 in 25—had to be introduced in order to gain La Cima at 10,018 feet, followed by a descent of 1 in 26 to reach Mexico City at 7,348.7 feet. When the engineers came to rebuild it was realised that such grades could not be retained for the heavier traffic, so a bold policy was adopted. All but 60 out of 220 miles were abandoned. A careful reconnaissance was made, and after scouring the country thoroughly the plotters came back with a southbound grade which gave no heavier

rise than 1 in 50. The proposal involved branching away from the old line at Gonzalez, and running via Queretaro, Huichapan, Apaseo, and regaining the old El Salto branch of the railway at Huchuetoca.

Even the old line was not left alone between Tlalnepantla and Lecheria. It had a maximum grade of 1 in 66 to get over the hill at Barrientos. This was cut out in favour of a bank rising 1 in 166 with a double track tunnel 734 feet in length as the principal piece of work. This latter change of line was carried out jointly by the Mexican Central and National Railroads before the consolidation. After leaving the Tula River the grades ran 1 in 66 for $8\frac{1}{2}$ miles, 1 in 100 for another $8\frac{1}{2}$ miles, and a reach of 1 in 66 for $4\frac{1}{2}$ miles, to gain the summit at an elevation of 7,840 feet, as compared with 10,018 feet at the Salazar summit on the old line. This new route parallels the old Mexican Central more or less, and is about 17 miles longer between Queretaro and Mexico City, but it has the advantage of grade, seeing that

its maximum is 1 in 100 between these two points as compared with rises of 1 in 66 and 1 in 57 on the former and shorter route.

Although the grading and bridging on the whole of the line was heavier than is generally justifiable on a new railway, the earthwork averaging about 42,000 cubic yards per mile, yet altogether nearly 40 miles of track were saved, while the engineers' reports pointed to an economy of £130 per day against the line via Toluca. The estimates were fully justified, since when the line was finished and put into service the first month's working showed a saving exceeding £4,300 in the fuel bill alone, with the result that the road, with its increased capacity and augmented traffic, paid its charges, plus the interest on the additional capital invested, and then left something over.

At places on this line the work was exceptionally heavy, especially on the stretch between mile-posts 65 and 70 out of Mexico, where the earthworks averaged over 150,000 cubic yards per mile. Near



ANOTHER VIEW OF THE GIANT MALLET LOCOMOTIVE.
The tender carries 7,500 gallons of water, and 3,300 gallons of oil.

mile-post 79 the location ran across a baranca 1,033 feet in width, and 126.3 feet below grade level. When this gap was reached a viaduct was suggested as being the easiest and cheapest, as well as quickest, means of spanning it. But the engineers

was finished so closely upon the calculated time that the trains crossed over the embankment on the day the metals reached it, though the grade was low and the work had not been completed to its full width. Still, the fact that trains could cross it,



BRIDGE OVER THE PAPALOAPAM RIVER, ON THE VERA CRUZ AND ISTHMUS RAILWAY.

The total length is 1,100 feet.

went into calculations very carefully, and they found that, taking steel at the price it cost in Mexico, freight and duty paid, a viaduct would cost as much as an embankment. The viaduct would take at least eight weeks to build after the metals reached the breach, while, on the other hand, if the gap were filled it was calculated that the embankment would be ready by the time the rails gained it.

Accordingly the embankment was decided on. A concrete culvert, 476 feet in length, by about 18 feet span, and with walls nearly 18 feet high, was built to carry the water in the bed, and the gap was filled up on either side with debris, about 400,000 cubic yards being used to bring the embankment to the required level. This embankment, still known colloquially as the "Big Fill,"

and that no delay had occurred to construction, represented a saving of over £100 per day, and this more than covered the additional outlay entailed thereby, while there is no costly steel structure to keep in condition.

Another very similar issue arose near mile-post 120. The locating engineer was confronted with a gap which he estimated would require some 250,000 cubic yards of spoil to fill. The alternative was a viaduct and a tunnel. The situation was discussed, but finally it was decided to turn the tunnel into an open cutting, and to dump the spoil removed therefrom into the gap, thereby eliminating the viaduct. To drive the cutting entailed the removal of some 40,000 cubic yards, but the hard, glassy lava proved harder to work



THE FIRST BRIDGE AND TUNNEL SOUTH OF TUXPAN, ON THE TUXPAN-COLIMA BRANCH OF THE NATIONAL RAILWAYS OF MEXICO.

than had been anticipated. Still, when the rails reached the cut, although they could have crossed it, track-laying was delayed for six days, but had a steel viaduct been introduced the delay would have been about three weeks longer.

During the recent period of construction—extensions have been maintained actively

The Arroyo Chico Bridge.

in conjunction with the rebuilding of existing lines—the railway running west from Durango to Llano Grande, a distance of 63 miles, offered some pretty problems. The line runs through a box canyon for some distance and in the guleh it became necessary to swing across the Arroyo Chico. The engineers at first proposed to provide a viaduct, but when the consulting engineers considered the problem, they pointed out that it would be impossible to secure satisfactory stiffness for the stipulated loading with towers of the height which were found to be necessary. Accordingly the viaduct was abandoned in favour of a cantilever bridge, with anchor arms of 105 feet, cantilever arms of 135 feet, and a suspended span of 120 feet.

One severe handicap to railway construction in the lower-lying tropical parts of

Climatic Difficulties.

Mexico is the climate, with its humidity, swarms of flies, gnats and mosquitoes, and abnormal rainfall. In some districts the latter averages about 15 inches per annum. These conditions are responsible for a pronounced shortage of labour, and even the native toiler will not tolerate them unless necessity compels. This deficiency does not apply only to construction, but to track maintenance as well. All the lines in the tropical districts of Mexico for years experienced supreme difficulty in getting men to serve as gangers and platelayers, and at times the permanent way fell into a deplorable condition. The Inter-oceanic was a particular sufferer in this respect. In 1905, however, this company decided to see whether the provision of stone

houses, with elevated floors and corrugated iron roofs for the section men, would hold out any inducement, and forthwith 50 such buildings were erected. The labour difficulty disappeared immediately. The peon of Mexico may be wretchedly poor, but he appreciates a good dry home for himself and his family. In view of the success of this experiment, all new lines in Mexico are now being provided with stone section houses, as they have proved to be one of the best investments on the railways.

The Vera Cruz and Isthmus Railway is destined to play an important part in industrial expansion and development. From the technical

New Trade Lines.

point of view it is not particularly interesting, the outstanding feature being the heavy bridging which has been found unavoidable. But by means of a new branch line just completed the prosperous San Andres Tuxtla tobacco-growing district will now be given direct transportation with the coast. Hitherto this business has had to be worked by pack mule trains over a trail of 35 miles, followed by two or three days' journey by river steamer, and finally a 40-miles' railway journey to Vera Cruz. Another railway of economic importance is that, 84½ miles in length, extending from Pénjamo, and running through a richly fertile arable district. Before the line was in service order transport was demanded, and 500 ear loads of grain were taken out by means of the construction trains.

But possibly the most important new line is that which is being driven from Tampico direct to Mexico City. When completed it will constitute a formidable rival

Tampico-Mexico Line.

to the British-owned Mexican railway which connects the two points by a line 265½ miles in length, and the Inter-oceanic, which has a line some 296 miles long between the capital and Vera Cruz. At the present time the National Railways

have to handle freight between Mexico City and Tampico by the roundabout route running via San Luis Potosi, involving a haul over some 606 miles. In spite of this drawback, however, very good time is made with the freight and passenger traffic, the record in this respect being little, if anything, behind that of the Vera Cruz route. This performance is undoubtedly materially assisted by the excellent facilities, natural and artificial, at the port of Tampico. By the new line the distance will be reduced to 296 miles, with grades of 1 in 200 upon the coastal plains, and a maximum of 1 in 50 upon the 81 miles among the mountains. By means of this railway a powerful incentive to the development of the new port of Tampico will be offered.

The severity of the grades and sharpness of the curves on many of the busiest sections of the National system has offered some pretty problems in economical operation. On the British Mexican line huge Fairlie engines are employed, but on the Government system articulated compound oil-burning Mallet locomotives have been introduced to work the goods traffic. These engines, of which twenty have been purchased from the Baldwin Locomotive Works of Philadelphia as a first instalment, are the heaviest ever brought into Mexico and are almost as large and as powerful as any in use on the railways of the American continent. The total length over engine and tender is 103 feet, by $10\frac{1}{2}$ feet wide, and 16 feet in height. Complete, in running order, they weigh nearly 227 tons, the weight of the engine being 150.89 tons, with 133.9 tons upon the drivers. The high-pressure cylinders are $21\frac{1}{2}$ inches and the low-pressure

cylinders 33 inches in diameter, the common stroke being 32 inches. The drivers are 56 inches in diameter, the driving wheel base 30 feet 1 inch, and the rigid wheel base 10 feet. The straight top boiler is 80 inches in diameter, and the working steam pressure 220 pounds. The fire-box is 12 feet long by $6\frac{1}{2}$ feet wide, the total heating surface of fire-box and tubes being 4,700 square feet. The tender of the Vanderbilt cylindrical type carries 7,500 gallons of water, and 3,300 gallons of oil—liquid fuel, which is so plentiful and cheap in Mexico, being used. These locomotives are designed more particularly for working over Tamasopa Mountain of the Cardenas Division, and also on the section between Mexico City and Cuernavaca, where the grades and curves are particularly adverse.



ON THE TUXPAN-COLIMA LINE.
The rails run parallel with the Tuxpan River.



THE LIDGERWOOD UNLOADER DISCHARGING MATERIAL FOR AN EMBANKMENT TO REPLACE A TRESTLE.

The trestle was 1,300 feet in length, and 210,000 cubic yards of earth were used in the embankment. The whole load is discharged by this means within a distance of 50 feet.

The Railway Builders' Heavy Artillery—II

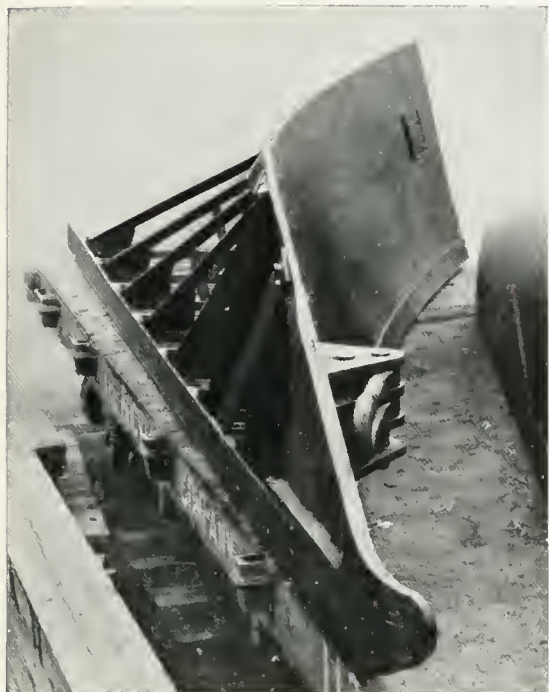
DEVICES FOR UNLOADING BALLAST WAGONS AND LEVELLING EMBANKMENT MATERIAL



DURING recent years the building up of lofty embankments, and the discharge of wagons laden with "spoil" taken from a cutting or the ballast pit, have undergone startling changes. The day of the navvy with his shovel throwing the spoil overboard from the trucks is no more; it is too slow and expensive for the present high-pressure times. Similarly, upon big works, the tiny ballast car holding no more

than a ton or two of material has given way to vehicles of greater capacity and different design.

The small ballast truck is an expensive piece of equipment in a large undertaking. A single mouthful of the capacious steam shovel is almost sufficient to fill it. Accordingly the evolution of larger cars, differing in design and operation from those generally employed, was but natural. These ballast wagons are of varying types. They may range up to 30 feet or more in length, and



THE LIDGERWOOD DISCHARGING PLOUGH.

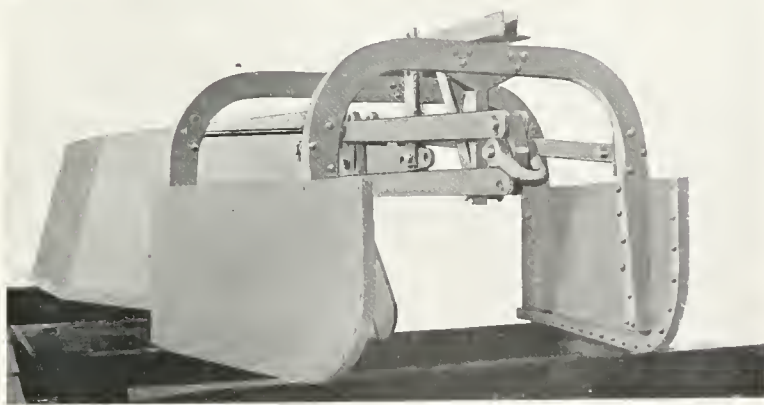
instead of being crazy-looking rough wooden boxes slung on wheels, are substantial trucks wrought of steel, capable of carrying from 40 to 45 tons of spoil.

Some of the vehicles are merely enlarged editions of the puny three- to five-ton trucks generally employed, the removal of the spoil from either side being carried out by manual effort. Such a system, however, is feasible only in those instances where labour is cheap, or where possibly the completion of the work within a short time is a secondary consideration. But in undertakings where high constructional speed with low cost is imperative they are impossible. Then one sees the hopper wagon with its floor sloping down on either side at an angle of 45 degrees or so. Each half of the floor is movable, through gearing controlled by a wheel, so

as to throw the spoil either on one or other side of the track, or if desired both parts can be opened at once, so as to drop the material vertically through the rails which have been laid temporarily upon trestling across a depression.

When the Lackawanna Railway decided to build its new line between Hopateong and Delaware Gap so as to avoid the heavy grades and sharp curvature on the old road, the railway builders hit upon an ingenious expedient to fill the huge rifts across which the new alignment ran. They stretched wire cables from massive wooden towers across the valleys. From this slender communication between the opposing banks of the gaps they suspended a light track, complete with sleepers. The ballast trains, in this instance, were composed of the small wagons, and they were backed by a small donkey locomotive on to this suspended stretch of rails, and were unloaded from mid-air, the spoil being scattered in all directions to pile up the embankment below. It was a somewhat novel idea in embankment-building, but it proved completely successful and economical in the case of the larger fills ranging up to 110 feet in height which demanded over 6,000,000 tons of spoil to bring the track to the plotted level.

But the tool which has brought embankment-building to its highest pitch of per-



THE BUCYRUS BALLAST DISCHARGING PLOUGH.
For emptying the contents of the wagons equally on each side.

fection, and which has reduced the factor of cost to its lowest point, is the Rapid Unloader. By means of this machine the expense of emptying the ballast train is so small as to be practically a negligible quantity. This system has been brought to its highest degree of efficiency and economy by the Lidgerwood Manufacturing

pulls being obtained with a steam pressure of 125 pounds at the steam throttle. If a higher steam pressure is used a correspondingly increased pull can be secured, inasmuch as the cable-pull is in proportion to the steam pressure, but this is at the expense of the life of the steel wire rope. Accordingly, in the interests of economy, the foregoing relationship between steam pressure and pull has been gained.

The whole of the machinery is mounted upon a heavy metal base weighing from 2 to $2\frac{1}{2}$ tons in order to secure rigidity and to keep the bearings in line, this being mounted upon the flat deck of the vehicle. The drum varies in diameter from 41 inches in the case of the 25-ton machine to 54 inches for the 60-ton unloader, while the large gear wheels driving the drum similarly are of 89 and 109 inches respectively, with faces of 8 and 10 inches. The drum gear wheel is driven through intermediate gearing, and on the shaft of the latter is the clutch which throws the drum in and out of action. The main control comprises levers for actuating the clutch, brake, reverse, and steam throttle respectively. Owing to the heavy varying work which the unloaders have to fulfil, all the gears are of heavy construction, those in the smaller machine being of cast iron, while those of the 60-ton unloader are of steel. The former machine complete measures 18 feet $3\frac{1}{2}$ inches in length over all, by 8 feet 8 inches in width, with a height, from the platform of the ear to top of the large gear wheel, of 7 feet, and weighs 17 tons. In the case of the 60-ton unloader the over-all length is 20 feet 3 inches by 9 feet $4\frac{1}{2}$ inches wide, and 8 feet 3 inches in height from platform level, the complete weight being $23\frac{1}{2}$ tons.

Upon the drum is wound a steel cable varying in diameter from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches according to the capacity of the machine, and of sufficient length to extend to the extreme end of the ballast train. At this point it is connected to a heavy steel plough so designed as to move along within the truck, being



THE BUCYRUS DISCHARGING PLOUGH AT WORK. It is pulled by means of a cable from the extreme rear to the front of the train.

Company of New York City, whose unloaders have accomplished extraordinary results.

This unloader comprises a small stationary engine and winding machine, which is built upon a flat truck, and is carried next to the locomotive, so as to be able to draw its steam from the boiler of the latter. The essential features are the winding rope, drum, and driving gear, whereby a pull of from 25 to 60 tons can be exerted, according to the type of the plant, these respective

guided in its movement by the side walls of the vehicle. The design of this plough varies according to the character of the work, the side upon which the spoil is to be dumped, and the nature of the material. In the Lidgerwood system the plough is a massive steel device, the blade of which is set at an angle of about 45 degrees across

even discharge of material over the sides of the truck.

The foregoing types are adapted to unloading "common" and "loose rock," but for unloading "rock" properly so-called, the angle system is preferred, owing to the varying dimensions and weights of the boulders upon the car. Moreover, in the



THE SPOIL FALLING FROM THE TRUCKS AS THE UNLOADER IS PULLED ALONG.
The sides of the Truck are top-hinged doors.

the width of the wagon; or, if the spoil is to be distributed equally over each side of the vehicle, it is double angled, the plough being in the centre longitudinal line of the truck. In order to guide the plough in its movement, stakes are fitted to the side of the wagons.

In the two-sided discharge system which has been perfected by the Bucyrus Company a slightly different design of plough is employed. The front, to which the hook of the cable is attached, comprises an arched section to the sides of which guide walls are riveted. The plough proper is placed behind and centrally to the front part. As the gauge of the latter is the internal width of the wagon, when the plough is pulled forward the front guides keep against the sides of the vehicle, so that the nose of the plough is kept central, thereby ensuring the

latter ease, as a rule, the cars are provided with only one wall, the opposite side being open, so that the vehicles represent flat deck cars with one side only. The latter enables the rock spoil to be banked against it, and at the same time serves as a guide for the plough, which is kept pressed evenly against it during movement. The advantage of such a type of car is that rocks of any size can be loaded and transported, whereas it might be impossible to take them in a boxed vehicle, while they can be discharged without any trouble whatever over the unobstructed side. In fact, masses of rock weighing as much as 10 tons have been shot off such vehicles without any effort, masses which it would be impossible to stow or discharge mechanically from any other type of wagon.

As may be supposed, with such a discharging or unloading system a special design of car is required; or, rather, the vehicle has to be adapted to the work. An ordinary deck truck is quite suitable as the attachments can be effected cheaply and

across the track receives the hook at the free end of the cable. The latter is wound upon the drum during transit, the unloader stopping beneath the derrick to facilitate this task. The train then moves forward and, the end of the cable being



RAILWAY BUILDING WITH

The machine for hauling in the cable attached to the plough is mounted on the truck next to the

quickly. All that is required when handling "common" or "loose rock" is that the two sides should be fitted with swinging top-hinged doors. Steel aprons are laid over the spaces between the ends of the cars so as to give a continuous deck from end to end of the train. The result is that a complete train resembles a long trench or ridge of earth, 500 feet or more in length, moved bodily to and fro along the track.

The operation of the unloader is very simple. The locomotive, with the unloader immediately attached, heads the train, while at the rear is the car carrying the plough. When the train has reached the point where the spoil is to be dumped there is a pause. A derrick or some other equally efficient device which has been rigged up

anchored, the rope is paid out until at last the plough comes beneath the derrick. The cable hook is then attached to the plough, and everything is ready for unloading. The operator of the unloader sets the machine going, and the cable is slowly wound in, dragging the plough through the trucks. As the earth is pushed forward by the advance of the plough, the side swinging doors are forced open, and the material is dumped upon the permanent way on either side of the track. The hauling is continued until the plough has been drawn up to the edge of the unloader car, by which time the whole train has been emptied. By this means the ballast cars are depleted of their contents quite as cleanly as if shovels were used, the plough

riding over the aprons bridging the spaces between the ends of the trucks with complete ease.

The outstanding advantages of the system are the speed and the low cost with which unloading can be completed. A train of

straight line, and will work without the slightest hitch upon the roughest, badly settled temporary construction track, even upon a heavy grade. The cost of the equipment necessary to work with the unloader also is reduced, as compared with



THE LIDGERWOOD UNLOADER.
locomotive, and the necessary steam for driving the unloader is drawn from the boiler of the locomotive.

seventeen trucks, each containing from 40 to 45 cubic yards of earth, can be emptied in five minutes. Instead of an army of men swarming over the trucks with their shovels, quite a few suffice for the complete operation, these following the plough to see that it completes its work properly. It is not even necessary to have a special operator for the unloader, as the fireman or driver of the locomotive to which it is attached, and from the boiler of which steam is taken, can supervise the operation of the machine.

The unloader does not require a good track, a tangent, or a level road to carry out its work efficiently. It can be manipulated so as to swing off the spoil on a curve as easily as upon a piece of level,

other systems. Flat cars of 50 cubic yards capacity may be used, and can be taken for the occasion from existing railway stock. Adaptation to the service does not entail an appreciable outlay nor occupy much time. Then when the work is completed the superstructure can be removed, and the cars returned to their normal service. On some of the railways where the Lidgerwood Unloader forms a conspicuous feature of the constructional equipment, a special truck is employed for stretching the cable preparatory to attachment to the plough. A crib is built up on a flat deck-car, and at a suitable height—clearing the load in the ballast cars—there is an arm with a shackle projecting over the side of the truck. This car is accommodated on a side track

beside which the ballast train is moving, its wheels being scotched to keep it stationary; the cable is made fast as the unloader passes, and then, when the rope has been extended to its requisite length, it is hitched on to the plough. It is not necessary to couple up the cable and plough at the point of discharge; it can be carried out at some other convenient point, the train continuing its journey with everything ready to set the plough in action at the desired moment.

With this machine the spoil either can be dumped at one point, such as around a trestle which is to be filled, or it can be distributed thinly, as in top ballasting, over a considerable distance. In the first case the load can be discharged in the length of the train, merely by keeping the locomotive

stationary and hauling in the plough; or, if unloading at a more concentrated point is requisite, after the unloader is set in motion drawing the train plough forward, the train is moved at a corresponding speed backwards. By this means the contents of a 20-car train, representing perhaps 1,000 tons, can be dropped within a space of 50 feet. On one railway where an embankment 1,300 feet had to be built up from a timber trestle, the whole of the 210,000 cubic yards of spoil required for the purpose were handled by the unloader. In distributing the spoil thinly alongside the metals the train is moved forward simultaneously with the hauling in of the plough, the depth of the layer varying according to the forward speed of the train.



THE LIDGERWOOD UNLOADER DUMPING ROCK FROM A TRAIN.
Showing plough and hauling rope.



A TYPICAL STRETCH OF TRACK AMONG THE MOUNTAINS ON THE PEKING-KALGAN RAILWAY, SHOWING SOLID CHARACTER OF THE GRADE.

By courtesy of the "Scientific American."

A Wonderful Chinese Railway

THE FIRST LINE TO BE FINANCED, BUILT, AND OPERATED SOLELY BY
CELESTIAL EFFORT



At the present moment China is considered to offer one of the finest territories for railway conquest, and in consummating this end no effort is being spared by the various Powers. British, American, French, German, Belgian, and Japanese interests consider the Land of the Dragon as an ideal centre for the pursuit of their activities, and the varied undertakings have stirred international jealousies to a supreme degree.

But to the British alone is due the glory of having introduced Stephenson's revolutionary invention into the land of the Celestials, though it proved by no means a simple or easy task. The Chinese, with their characteristic contempt for things occidental, did not view the steelway with enthusiasm. Every conceivable objection was raised, and when at last Messrs. Jardine, Matheson and Company, owing to their intimate commercial relations, suggested the idea, they met with an opposition

which startled even them, notwithstanding the fact that they were pretty familiar with the ways of the "heathen Chinese." Some time elapsed before sanction was extended for the construction of a short railway about 20 miles or so in length in the south.

coolie was run over and killed. British opinion leans towards the theory that this untimely death was courted purposely, just to bring the newfangled notion into national disrepute. Whether it was an accident or a suicide the result achieved



THE STAFF OF CHINESE OFFICIALS WHO BUILT THE PEKING-KALGAN RAILWAY.
His Excellency Jeme Tien Yow, the engineer-in-chief, is in the centre.

By courtesy of the "Scientific American."

The laying of the metals did not proceed smoothly by any means. Millions of spirits were threatened with disturbance, and it was by no means an easy matter to plot a line which should pay every required respect to native superstition. But at last the job was finished and the trains commenced to run. The promoters of the enterprise thought that at last they had worn down Chinese antagonism, and that the benefits of the railway soon would become appreciated. But they were speedily disillusioned. One day a

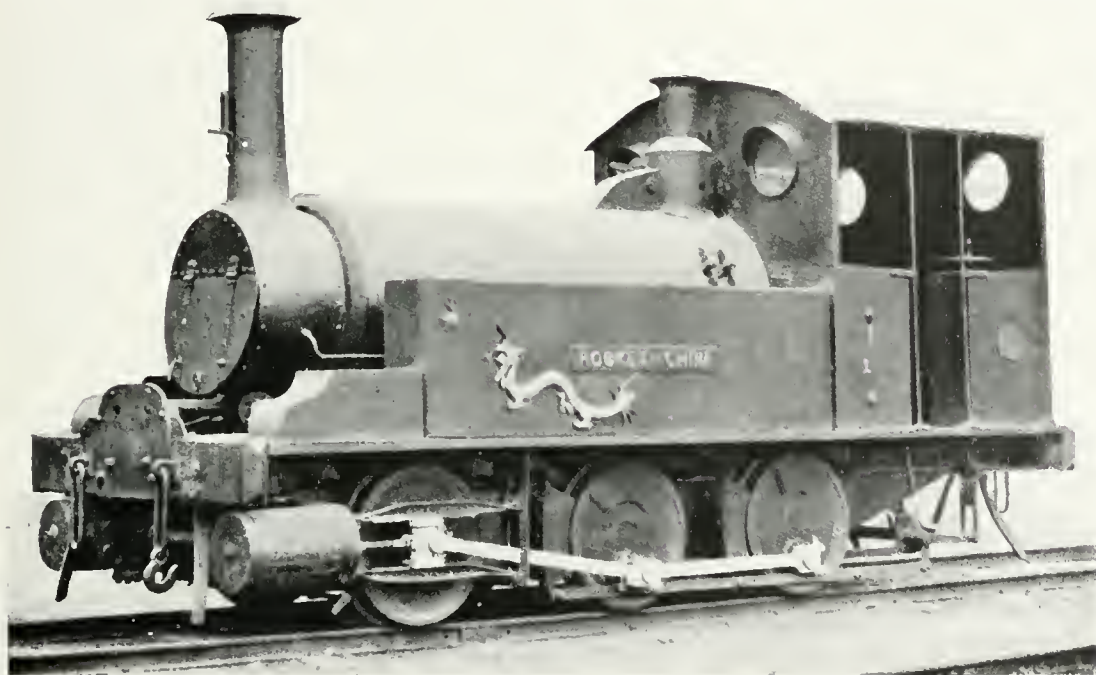
the natively desired end. The inhabitants of the district rose up *en masse*; their fury was such that they tore up the line and threw the rails and sleepers into the sea. Some scraps were saved and were shipped to another Eastern territory where the railway was not regarded with such hostility. The Imperial Government, in order to appease the wrath of the populace, decreed that nothing pertaining to the nature of a railway should be laid in any part of the kingdom from that time forward, and every concession which had

been conceded was rescinded there and then.

This drastic action came as a severe blow to the interests which had fathered the introduction of the railway into China. But their disappointment was trivial in comparison with that of Mr. Kinder, the

gauge tramway, with mules for hauling the cars.

But Mr. Kinder had no use for animals when steam traction might be employed more profitably. He suggested to Tong King Sing, the guiding spirit of the mining enterprise, that a steam locomotive should



Photograph by courtesy of F. A. Foster, Esq.

THE "ROCKET OF CHINA."

The first locomotive built in China by Mr. Kinder, C.M.G., from odds and ends rescued from scrap-heaps. To escape the fury of the anti-railway section of the Government it was buried—to be resurrected when the wave of antipathy had passed.

present great grand old British "Railway King" of China, now controlling the Northern Imperial system. At the time he was resident engineer at the Kai Ping coal fields, in the neighbourhood of Tang-Shan. Chinese merchants of a progressive spirit supported this enterprise, and, unlike the majority of their compatriots, they favoured the railway, more particularly as they had a 29 miles' cross-country haul to Pehtang, at the mouth of the river of that name. Railways being ruled out of court, the Chinese merchants built a canal to a point within five miles of the coal fields, and the remaining section of country was spanned by a narrow-

be used. This enlightened official agreed with the proposal, but, aware of the antagonism to the locomotive, urged that they should proceed warily. He suggested that possibly an engine might be built on the spot, but Mr. Kinder, reviewing the facilities at his disposal, was somewhat sceptical of success. Tong King Sing, however, maintained that this would be the better course to pursue, as no alarm would be raised; it might be possible to introduce the engine unawares and to run it, thereby wearing down the existing prejudice unconsciously. Mr. Kinder realised the wisdom of the argument and agreed to do the best he could. He widened



WORKING TRAFFIC OVER THE SUMMIT ZIGZAG IN THE NANKOW PASS.

By Jerni

the tramway to the standard gauge of 4 feet 7½ inches, and then cast among the various scrap-heaps to rescue odds and ends which might suit for the integral parts of a locomotive. He found an old upright hoisting steam engine, and promptly annexed this to furnish the boiler and cylinders. Another rubbish-heap furnished six cast-iron carriage wheels. Diligent search among other junk piles supplied materials for various other parts, while he took some channel iron from the headgear of a mine shaft to fashion his frame. With this flotsam and jetsam he built a small 2-4-0 tank engine. It followed the conventional lines so far as the peculiar circumstances would permit, though it was a trifle quaint in its general appearance. But he succeeded in his task, and he promptly dubbed his production the "Rocket of China," after its famous British namesake. Probably it was the cheapest engine which has ever been built, for the total cost was only between £75 and £80, exclusive of the old material which was rescued.

But news reached the Imperial Government concerning the Britisher's ingenuity, and it summarily ordered the work to be stopped. The official intimation was disregarded. The Government became incensed at this flagrant flouting of authority, and announced that it would dispatch a Commission to the mines to investigate the truth of the reports upon the spot. If an engine were found dire penalties would be meted out. Mr. Kinder and his colleagues received wind of the movement, and recognising the serious situation with which they were confronted, made arrangements accordingly. A huge pit was dug, and into this the offending locomotive was dropped and carefully buried. When the Government Commission reached the mines no trace of the reputed locomotive was to be seen; the cars were being hauled by mules in the usual manner. Once more rumour had proved to be a lying jade, and the Commission departed homewards in chagrin, somewhat incensed against those who had spread the alarming news.

At that time Li Hung Chang was an unequivocal antagonist to railways, and forthwith the influential mining officials devoted their energies to winning him to the new order of things. Their first approaches were rebuffed, but they clung to their task, and at last succeeded in impressing His Excellency with the advantages of steam traction. At this juncture it was deemed safe to resuscitate the "Rocket," so the grave was reopened, the engine exhumed, overhauled, and put to work once more. Then the wily mine owners suggested that Li Hung Chang should come down and see the engine at work, just to appreciate what it could do. He did, and was convinced, though he kept his opinion to himself, but ever after became a firm adherent of railway development. Gradually the length of line was extended, and although the enterprise experienced numerous vicissi-

tudes, Mr. Kinder stuck to his work and finally won out. The crowning stroke came when the Government desired to improve facilities for moving the troops from point to point quickly. "Why, it can only be achieved in one way," remarked certain Court officials interested in the idea; "that is by railway. If the Tai Ping coal road is extended it will be possible to move the soldiers from the coast to the capital in a matter of a few hours instead of days." The Government, ever careful of its own safety, appreciated the argument and sanctioned the extension.

Some thirty years have passed since Mr. Kinder, by his striking display of tenacity of purpose and enterprise, established the utility of the locomotive, and in the meantime great changes have been wrought. Powerful financial interests of all nationalities have over-run the country with some 8,000 miles of line. Yet so far as China is concerned the movement is only in its infancy; projected lines represent more than double the mileage of that already in operation.

In this forward move the Chinese have been content to assume the rôle of apathetic spectators. They have left the grid-ironing of their land to foreigners, borrowing money on exacting terms to finance the various schemes. This attitude is resented by the more enlightened and progressive members of the community. "Why not build our own lines!" is a frequently heard cry. The retort is that the Chinese are not sufficiently skilled to achieve this end, no matter how desirable it may be. And so the Powers have triumphed at the expense of apparent Celestial ignorance.

But some six or seven years ago the invaders received a rude shock. A suggestion was made that a railway should be built from Peking to Kalgan on the famous caravan route to Russia. Seeing that the line was to traverse some of the most difficult country in the Empire, it is not surprising that in the beginning it was

**Railways
Accepted.**

suggested that the enterprise should be handed over to outside interests. But the progressive members of the country took a firm stand. We can build this line ourselves, and we can find the money to

construction. He graduated at Yale in 1883, and then came to England, where he studied in a technical school for several years. Returning home, he entered the Imperial Railways of Northern China under



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A TUNNEL AND CULVERT ON THE PEKING-KALGAN RAILWAY.

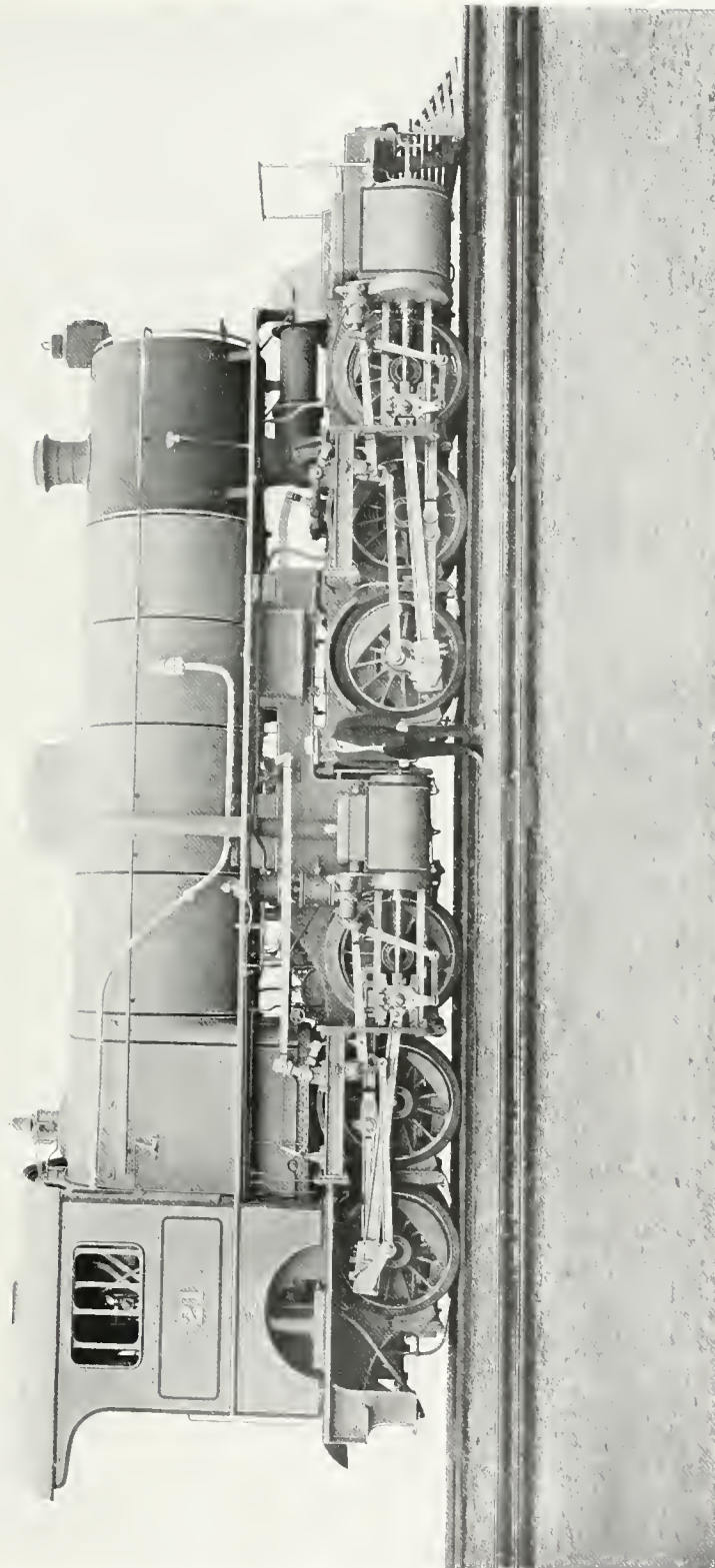
The structure to be seen in the background is the inner wall which runs parallel to, and within a mile of, the Great Wall of China.

defray the cost, so we will do it. The foreign engineers scouted the suggestion, and laughed at Chinese ambitions. But the authorities were not dismayed. The decree ran that the line should be financed, engineered, and built by the Chinese.

Success depended upon the discovery of an engineer competent to carry out the scheme. This did not prove a difficult task. Some years previously, in 1880, a number of Chinese students had been sent to the United States to receive university training. Among these was Jeme Tien Yow. He alone took up civil engineering, especially in its relation to railway

Mr. Kinder, the builder of the "Rocket," where he became familiarised with railway problems upon the spot. His advance was rapid, and he attained one of the highest positions in the service.

When the Peking-Kalgan railway emerged from the chrysalis stage the entire duties of chief engineer were entrusted to the young anglicised Chinaman, who had proved his worth under Mr. Kinder. He at once rallied his native forces, and, the financial questions being settled, he made the preliminary surveys during the summer of 1905. He ran his lines as far as the Nankow Pass, and



Photograph by permission of the North British Locomotive Co. Ltd

A BRITISH-BUILT MALLET ARTICULATED COMPOUND LOCOMOTIVE (0-6-6-6-0) FOR HAULING THE TRAINS OVER THE NANKOW PASS UPON THE PEKING-KALGAN RAILWAY.

The engine weighs 96½ tons in running order.

evolved a first-class location over the first 32 miles, construction upon which was commenced three months later.

In inaugurating the building department no white labour of whatever description was employed. Chinese

Chinese Labour Throughout. were requisitioned, from the

coolies for the camel transport to the highest positions, and railway building in China never proceeded so smoothly as was the case upon the Peking-Kalgan railway. There were no petty squabbles between the navvies and the labour contractors, nor between the latter and the chiefs, for the simple reason that all spoke the one tongue, so that no misunderstandings arose. Moreover, the work was carried out more economically than upon any previous undertaking. All intermediary profits arising from sub-letting and re-sub-letting were eliminated. In fact, it is doubtful whether a first-class line ever has been built at such a low price—at all events, not in China. The cost of the earthworks on the first division did not exceed one penny a cubic yard; broken stone for concrete averaged from 6½d. to 1s. 4d. per cubic yard, while sand for concrete ran at about 1½d. per cubic yard.

The first 32 miles out of the Imperial capital runs over a drab, uninteresting plain, lifeless except for the pack trains of mules, donkeys, and camels, laden with furs brought from Mongolia for the Peking market. Yet, although the country is tolerably flat, great difficulties were encountered. The first wet season following the completion of this section brought the heaviest flood known for forty years, which submerged the country and washed out the railway embankment to such an extent that some £32,000 had to be expended to repair the damage. In order to protect the steel highway against a repetition of such a disaster heavy retaining walls were built, while numerous massive concrete culverts were

introduced to carry off the surplus waters. On this Luitsin division, as it is called, there are no fewer than 21 bridges and 17 culverts. All are of a permanent character, wrought in steel or concrete. The largest bridge is approximately 300 feet in length and comprises five spans, each of 30 feet, and one of 110 feet. The whole of the steel for this structure, with the exception of the long span, which was built in England, was prepared in Chinese shops, and the same applies to all other metallic structures upon the line.

The heaviest and most trying piece of work encountered in the whole 130 miles was the negotiation of the Nankow Pass, through which **The Nankow Pass.** the main caravan road wends

its northward way through the Great Wall. The mountains tower up abruptly from the plains, and it became necessary to rise 1,800 feet in 10 miles. His Excellency Jeme Tien Yow, having been drilled in the modern railway building school, endeavoured to plot a line conforming with present trunk line conditions, free from heavy banks and sharp curvatures.

Finally a feasible route was obtained showing a minimum curvature of 1 in 600. Heavy tunnelling was found unavoidable. The alignment for the most part follows the contour of the mountain sides, involving heavy side-hill excavation, with embankments carried across gullies and around spurs. As a matter of fact, the 13 miles through the Pass is nothing but a succession of big cuts, deep fills, and tunnels, with bridges and culverts spanning the torrents and gulches. The outstanding feature of this section of the line is the protective work. All the retaining walls are built of solid granite, and in many cases the mountain torrents are provided with heavily cemented channels so as to eliminate erosion.

Four tunnels were found to be unavoidable upon this section of 13 miles, their respective lengths being 1,200, 150, 450,

and 3,580 feet. The first tunnel, near the foot of the Pass, traverses limestone, and was driven in six months, but the three other tunnels extend through solid granite. The last, which leads to the summit of the Pass, is the biggest and longest work of

stantial character can be built by the Chinese.

As the Nankow Pass section of the railway is the most trying from the operating point of view, owing to its grade and curvature, three special engines have been



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ONE OF THE SHORT TUNNELS IN THE NANKOW PASS.

its kind in China, while it burrows 200 feet beneath the Great Wall. Despite the unusual magnitude of this task, the tunnel was completed within a year, and, in common with the other works of this class, is lined throughout with concrete, the portals being finished and faced in the same material. By the time the summit of the Pass was gained 640,000 cubic yards of spoil, half of which was solid rock, had been excavated, while the embankments required some 275,000 cubic yards of material. To complete these 10 miles of difficult track only £37,500 was expended upon labour, which affords some idea of how cheaply railways of the most sub-

stantial character can be built by the Chinese. They are articulated compound Mallets of the 0 6 6-0 type, which were built by the North British Locomotive Company, Limited, and are fine, powerful engines of their class. The low-pressure cylinders are 18 inches and the high-pressure cylinders $28\frac{3}{4}$ inches in diameter, with a common stroke of 28 inches. The drivers are 51 inches in diameter. The rigid wheel base is 9 feet 8 inches, and the total wheel base of the engine 29 feet 4 inches. The heating surface is as follows: Tubes, 2,425 square feet; fire-box, 166 square feet—an aggregate of 2,591 square feet. The fire-grate area is 45 square feet. Steam is

used at a pressure of 200 pounds per square inch, and the tractive effort at 50 per cent. of the boiler pressure is 35,576 pounds. The total weight of the engine in working order is 96.5 tons, the whole of which is available for adhesion.

These engines are stationed at Nankow, at the foot of the Pass, and they lift the trains to Ching Lang Chiao, a distance of 13 miles; the average train load is about 180 tons, exclusive of the locomotive, and they overcome the Pass in about two hours, a smart performance, considering the heavy character of the road. In order to obviate the possibility of the train breaking away, the engine pushes the load from the bottom of the Pass to the apex of the summit zigzag, where a smaller locomotive picks up the train and hauls it on to Kalgan.

Emerging from the mountains, the railway enters a lofty plateau where little difficulties of a technical nature were encountered beyond heavy bridging and providing numerous concrete culverts to cope with the flood waters. The most important piece of work on the 38 miles of this section is the bridge, 1,000 feet in length, having ten 100-foot spans, near Huilashun. The fourth division of 38 miles, extending from Kimingyi, proved almost as difficult to build as the 13 miles through the Nankow

Pass. At Hsiangshupo a heavy drive through granite and sandstone had to be made for a distance of 16,500 feet, the depth of the cutting varying from 10 to 85 feet.

From the constructional point of view the Peking-Kalgan railway compares favourably with main lines which have been built in other countries during recent years. It is a single track of standard gauge, heavily ballasted, and with 85-pound rails spiked, instead of being chaired, to Japanese or creosoted sleepers. On the sidings and branches 60-pound rails are used. The permanent buildings of the stations likewise are completed upon substantial lines, stones being used liberally.

The rolling stock is of the most up-to-date type. The road engines were built in China, and the majority of the passenger coaches are a hybrid between the British compartment and the American centre-aisle types.

The line has proved a success from the financial point of view, and its extension into Chinese Turkestan, so as to link the outermost western parts of the Empire with the seat of Government, is being contemplated. The cost of the undertaking was defrayed completely out of the surplus earnings of the Government lines in North China.



A TYPICAL BRIDGE ON THE PEKING-KALGAN RAILWAY.

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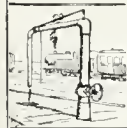
THE ELECTRIC LOCOMOTIVES WHICH HAUL TRAINS THROUGH THE CASCADE TUNNEL.
The energy is generated in Tumwater Canyon, 33 miles distant.

Harnessing the Snow

HOW THE AMERICAN GREAT NORTHERN CIRCUMVENTS THE CASCADE MOUNTAINS

ELSEWHERE I have related how snow ties up a railway and how it has come to be regarded generally as the steam steed's worst enemy. But here and there it has been found possible to turn this implacable foe into the railway's best friend. The most illuminating illustration of this development is offered by the American Great Northern Railway upon the Cascade Mountains division. The heavily saturated clouds drifting in from

the Pacific encounter their first obstacle in this rampart, with the result that the snow-fall during the winter is terrific. So much so that the snow-ploughs have to stand by with steam raised and their crews on the alert. Upon the gathering of the clouds around the lofty ragged crests, the alarm is given, and the snow-fighting train moves out, crawling slowly towards the summit so as to be ready to fight the descent of the white fleece. Here and there huge supplies of coal are stored during the summer, so that the snow trains may not run short of



fuel. Down in the station yards monster engines, with fires well coaled and the safety valves humming merrily, are vigilant to give a passing train a lift over the hard, slippery road, while in the shacks lounge

their utmost in the struggle to keep the traffic moving. At Everett, on the Pacific coast, the rail is 26 feet above the sea level, but in the course of the next 75 miles the train has to toil to an altitude of 3,341 feet.



HOW THE AMERICAN GREAT NORTHERN DESCENDS THE PACIFIC SLOPE.

Showing the three tracks which are connected by huge loops. The engines are backing down the grade to push up another train from the bottom. In the distance may be seen the train which they have helped up, and which has wormed right round the valley.

gangs of men, ready to rush out to repair a bridge which has been carried away by an angry swirling torrent or an avalanche. Day in and day out, from the first call of winter till mid-spring is gained, these arrangements prevail, for the fight is grim, and the snow descents sudden and unexpected.

This is a wonderful road to keep open for the heavy transcontinental traffic, and often the engineer's resources are taxed to

The rise is so abrupt, especially in the last 25 miles to the summit, that the plotters of the line had to introduce a steady continuous rise throughout that distance of 2.2 per cent.—1 in 45—and even then were so pushed for space that they could not carry their road directly forward, but had to zig-zag the mountain slopes, with the result that three tracks, one above the other, like terraces carved in the face of the cliff, may be seen from the bottom of

the valley. It is a marvellous piece of engineering, difficult to parallel in any other part of the North American continent. Overcoming the summit, the descent on the eastern side is equally sudden for another 30 miles, as the rails drop from an altitude of 3,341 to 1,158 feet in that distance.

When the line was first laid the summit was overcome by a wonderful zig-zag, which the engineers described on the side of the mountain cone. The train backed up one slope, was hauled up the second incline, backed up the third level, then steamed up the fourth step and thence down the other side. Four tracks zig-zagging the cone could be seen, and it was an inspiring sight to watch the "Limited" being put over the summit, the 230-ton train having a double header and a pusher to maintain about six miles an hour. As may be supposed, the demand upon locomotive effort was enormous, and even the engines, monsters of their day, experienced a stiff battle against the grade to get to the top. When the snow came the zig-zag was thrown all sixes and sevens, because the tracks became buried to a depth sufficient to cover the coaches.

However, the zig-zag was merely a temporary measure. "Jim" Hill, who had planned the Great Northern, had decided upon an easier summit crossing—a tunnel. But seeing that the latter was four miles in length, and would occupy time to complete, he ordered the zig-zag to be built, so that traffic might be able to get through. The tunnel is single-track and is laid upon a maximum grade of 1·7 per cent.—1 in 59—from portal to portal.

The provision of the tunnel eased the situation somewhat, and as locomotives developed in power it became possible to lift a train weighing 900 tons over the hill with two Consolidation engines, each weighing 153 tons, as a double header. When the road was slippery a third engine of this

class was attached to the rear to serve as a pusher.

This was expensive locomotive effort, but was impossible of improvement until the Mallet articulated locomotive established its possibilities. With-
Monster Mallets.
out delay monsters of this type—2-6-6-2—were built for mountain service. They were big compounds with cylinders of 21½ and 33 inches diameter respectively, by a stroke of 32 inches, using steam at a pressure of 200 pounds, and weighing, in running order, complete with tender, 225 tons, of which 141 tons were available for adhesion. The driving wheels were 55 inches in diameter, while the boiler gave an aggregate heating surface of 5,700 feet, the grate area being 78 square feet.

Five engines of this class were acquired for service among the mountains, and they were put to work on the 2·2 per cent. hill, running to and fro over a distance of 109 miles. During the first winter they were neither turned nor taken into the engine-sheds. They were regarded purely as experiments, inasmuch as they were quite foreign to American working, the Great Northern being one of the first roads to take up the Mallet. The original intention was to use them as pusher engines, dispensing with double heading, and to assist the road Consolidation and its load over the hill.

The runs revealed a curious state of affairs. It was found that with these Mallets the train load could be increased to 1,160 tons, but of this total the Mallet pusher handled 614 tons, and with no more coal consumption than that of the Consolidation handling the difference of 446 tons on its end of the train. Forthwith it was decided to dispense with the Consolidation engines entirely in favour of Mallets for the road work. Accordingly twenty-five of the latter were purchased. These were somewhat smaller than the pushers, the low-pressure cylinders on the



THE "ZIG-ZAG" WHEREBY THE CASCADE MOUNTAINS WERE NEGOTIATED
The Great Northern Limited, of seven Pullmans, weighing 280 tons, had to be lifted over the steps of the temporary line was abandoned



DURING THE PERIOD THE CASCADE TUNNEL WAS UNDER CONSTRUCTION.

zig-zag by means of three locomotives. In the photograph four tracks are to be seen. This expensive directly the tunnel was completed.

front engine being of 31 inches, and the high-pressure cylinders on the rear engine having a diameter of 20 inches, with a common stroke of 30 inches. Complete with tender they weighed 201 tons, had a total heating surface of 3,914 square feet, and a grate area of 53.4 square feet, while the

resulted in its supersession of every other type of locomotive upon the mountain divisions of the Great Northern Railway, and its development has culminated in the introduction of the mammoth "Bull-Mooser," previously described (page 48), for freight business.



BUILDING THE PORTAL OF THE CASCADE TUNNEL.

boiler pressure was the same as in the larger engine—200 pounds.

When these were completed the whole system of working the mountain division was changed. With the smaller Mallet a train running up to 1,428 tons could be hauled right over the mountains, the larger engine being attached only as a pusher upon the 2.2 per cent. banks. Yet, although the train was increased in weight, the coal consumption was no heavier than had prevailed under the method of working with Consolidations, although the tonnage per train was increased by over 50 per cent. This remarkable triumph of the Mallet has

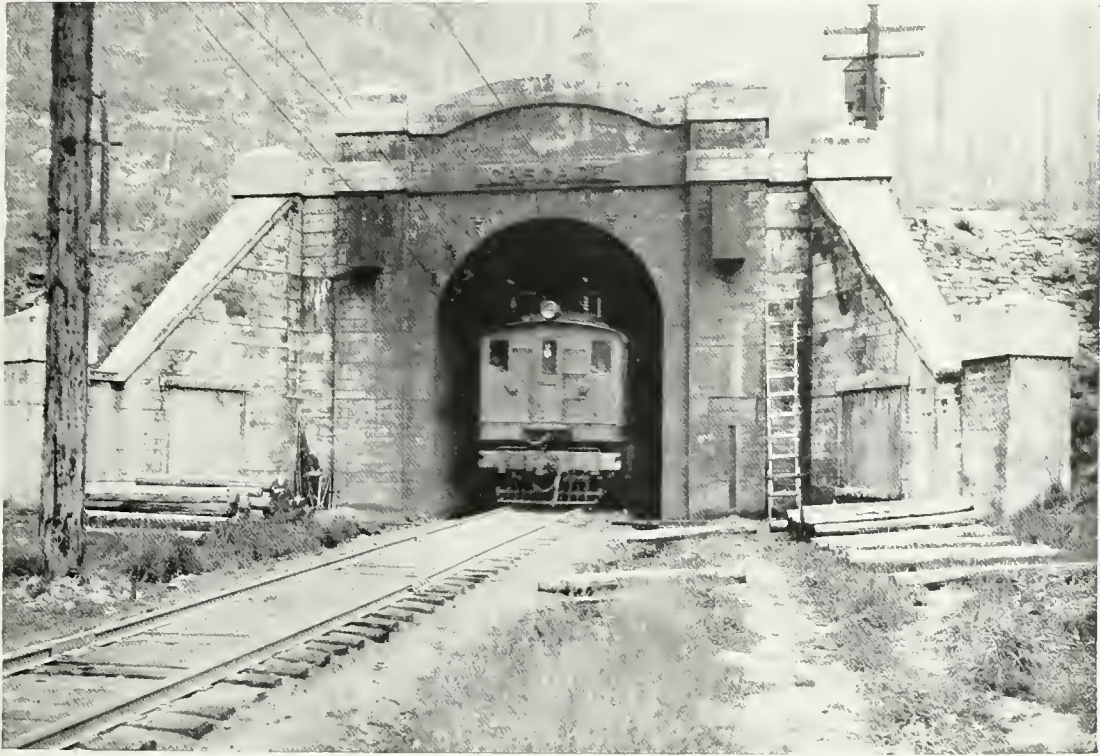
Despite these advances in regard to the locomotives there was one serious hindrance to further development—the tunnel. Being only a single track, and four miles in length, about half an hour was occupied in its negotiation, because, as the steam trains maintained a speed of only about 8 miles an hour against the grade, owing to the fouling of the bore arising from the steam engines working against the collar, the number of trains which could be passed through per day became strictly limited. Mr. James J. Hill realised that the tunnel was certain to throttle the expansion of the system unless its capacity were in-

creased. At first it was decided to drive a second tunnel through the mountain, but the engineers pointed out that the tunnel capacity could be increased very appreciably if electric traction were adopted.

The governing force of the line debated the question, and, after a personal in-

conditions. Ample water-power was available, as the heavy snowfall is responsible for innumerable torrents and freshets which thunder down the mountain slopes, and on the east side swell the Wenatchee River very considerably.

The engineers scoured the valley to

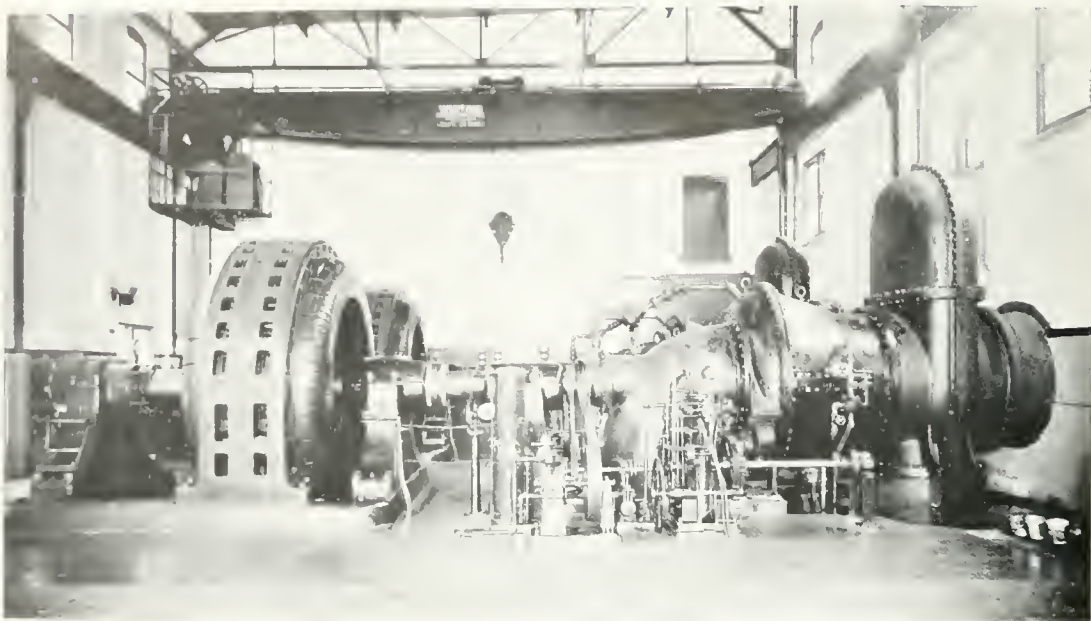


THE WESTERN MOUTH OF THE CASCADE TUNNEL, SHOWING ELECTRICALLY-DRAWN TRAIN EMERGING.

spection of the situation, thereby grasping precisely what the engineers proposed to achieve, Mr. Hill sanctioned the proposal. The engineers were given a completely free hand to "put the division in shape," as the undertaking was described by "Jim" Hill, and he, in his characteristic manner, troubled them no more until it was done, and he was in a position to judge its worth from the traffic results.

It was decided to carry out the electrification scheme upon the three-phase system, the various authorities who investigated the issue conceding that this was the most suitable and economical for the prevailing

discover the most favourable site for the dam to impound the water, so as to secure an adequate and continuous pressure to the water turbines. It was essential to secure a point where an all-the-year-round supply could be maintained, and where, at the same time, the hydro-electric station would be safe from avalanche attack. Finally a spot in a narrow canyon 33 miles east of the tunnel was found to offer the best site for the power-house. The river itself is impounded $1\frac{1}{2}$ miles above the electric station. Here a dam 1,700 feet in length, by 50 feet thick at the base and 30 feet high, wrought



GENERAL VIEW OF THE TURBO-ELECTRIC GENERATING PLANT.

in concrete, was erected, and the water thus banked up is led to the power-house through a wooden flume. This is a continuous pipe built of wooden staves firmly hooped with iron bands spaced about six inches apart, and having an external diameter of $8\frac{1}{2}$ feet. The difference in level between the dam and the power-house is 210 feet, and the pipe has a steady continuous fall from the former to the latter, being carried through tunnels and finally swung across the river to enter the building over a steel bridge.

This flume delivers the water to the three turbines at a steady pressure of 110 pounds per square inch. To ensure that this pressure should never vary at the power house, there is a standpipe, of the same dimensions as the flume, 210 feet in height. This standpipe takes up all the "surges" in, and acts as a governor upon, the water-flow, so that the pressure on the turbine wheels remains steady.

The power-house contains three 2,000 kilowatt generators connected direct to the water turbines. The current at a potential of 33,000 volts is transmitted from this power-house, by an overhead

line, 33 miles in length, to a sub-station at the tunnel mouth, where the current is stepped down and fed to the trolley wires at 6,600 volts.

The electrification scheme embraced the tunnel and the approaches on each side, involving about 21,000 feet of right-of-way, and about 6 miles of single track including sidings. The whole of the conversion was carried out by the General Electric Company of Schenectady (U.S.A.), who also designed and supplied the electric locomotives.

The latter are of the 0-4-4-0 type, comprising two coupled four-wheel trucks with two motors mounted upon each bogie. Each motor develops 250 horse-power, making 1,000 horse-power for the complete locomotive. They are rated at 91 amperes, at which they develop a speed of 15.2 miles per hour; have a rated tractive effort of 25,000 pounds, and a maximum tractive effort of 57,000 pounds. The eight driving wheels are 60 inches in diameter, while the total wheel base is 31 feet 9 inches, the rigid wheel base being 11 feet. The over-all length of the locomotive is 44 feet 2 inches, while the height

over the box eab is 14 feet 3 inches. The total weight of the engine, in running order, is 102·6 tons, of which the electrical equipment represents 47·2 tons, and the mechanical 55·4 tons. The whole of this weight is available for adhesion, so that the weight per axle comes out at 12·8 tons.

Each engine is able to haul the maximum train load handled by the Mallet engines through the tunnel and up the bank of 1 in 45 with ease at 15 miles an hour. Train loads of 2,000 tons have been hauled at this speed through the tunnel. When abnormally heavy loads have to be dealt with, a double header is employed. By means of these electric locomotives trains now traverse the tunnel in about 15 minutes, as compared with 25 to 30 minutes which prevailed under steam operation. Accordingly the train capacity of the tunnel has been doubled, while the

tonnage capacity has been more than trebled.

By the time the work was completed a round half a million pounds had been expended, of which the dam alone absorbed over £250,000.

The success of this undertaking has been complete, and has offered a very interesting illustration of how the snow, which in winter is so sorely dreaded, and which wreaks such devastation at times upon one part of the line, may be tamed to perform useful work the whole year round, because the Wenatchee River depends upon the melting snows in its higher reaches. Instances of similar harnessing of snow are offered in other countries, notably Switzerland, where the electrically operated mountain railways through the Simplon and Lotselberg tunnels depend upon the mountain torrents fed by the melting snows for the generation of the necessary energy.



THE POWER-HOUSE IN THE TUMWATER CANYON.

The water is drawn from the Wenatchee River at a point $1\frac{1}{2}$ miles away.



THE RISE FROM THE UPPER STATION TO THE EDGE OF THE PLATEAU ON THE USAMBARA AERIAL RAILWAY.

Showing the clearing through the jungle

The Steepest Aerial Railway in the World

A LINE WHICH PIERCES THE TROPICAL AFRICAN FORESTS TO AN ALTITUDE OF 6,600 FEET



CEDAR is a wood for which there is an urgent and increasing demand, but, unfortunately, the supply is diminishing. The greater part of the visible and accessible forests has been depleted, and, unhappily, for the most part, in a wasteful manner. When the pioneer settlers of the United States and Canada set out to conquer the soil, the dense masses of cedar worried them sorely. The straighter trees were cut

down, trimmed, and used for fencing purposes; the remainder were burned off as scrub. When the cedar-working industries roped in the virgin forests for industrial purposes they demolished their resources in a reprehensible manner. Only the finest trees were selected for their purposes; the others were destroyed. Nor was economy displayed in cutting up the wood. It was considered to be an unnecessary precaution. "Why, there is enough to last for centuries." So reasoned the despoilers.



PROFILE OF THE USAMBARA CABLE RAILWAY.

To-day cedar is so scarce that the merchants are carefully examining the stumps of the trees left by the early cedar jacks, cutting out every square inch of sound wood, while the cedar fences are being pulled down and the wood sold at high prices. The five continents are being scoured for untouched reserves, and among those participating in this hunt were a number of prospectors acting on behalf of a German company. Naturally, their investigations were confined, for the most part, to German territory, and ultimately their diligence was rewarded. They scaled the highlands of the Usambaras of German East Africa, and in those dense, untrodden, and well-nigh inaccessible forests discovered huge groves of this timber, which closer examination proved to be of the highest quality.

Immediately arrangements were completed to exploit these reserves. But one serious difficulty loomed up. The cedar jungle was at an altitude of 6,600 feet,

and there was a sheer drop of 5,000 feet to the Pangani Plains below. How could the lumber be got down? Surveyors probed the mountain sides assiduously, but they returned with dismal reports. A railway could not be laid, even for a few miles, except

at an expenditure out of all proportion to the value of the wood, while the interest and maintenance charges upon the capital cost of construction would render it impossible to market the wood at a reasonable price. The concessionaires thereupon debated an alternative method of transportation. They sought the assistance of the Bleichert Aerial Transporter Company, of London, to ascertain the feasibility of an aerial line. The latter dispatched their own plotters to the East African lumberland. Survey lines were run anew in all directions, and plotting made upon an elaborate scale.



BIRD'S-EYE VIEW OF THE MOUNTAINS AND LINE OF THE USAMBARA AERIAL RAILWAY.

The project which their surveyors outlined offered a complete and economical solution of the problem. It was a bold idea, because the length of the line was reduced to the minimum, and involved some daring and unusual work.

The scheme was accepted, and the aerial railway builders were soon swarming over the Usambaras, rounding up native labour, driving trails through the matted forest

within more satisfactory shorter lengths. Leaving the saw-mills at New Hornow, the line makes a gradual rise of 295 feet in 3,960 feet to gain a point 5,220 feet above sea level, and 4,995 feet above the lower terminal. In order to reach this summit it was found necessary to drive a deep cutting through the crest of the mountain, down the centre of which the steel towers are planted. Care had to be observed to provide facilities for carrying off the flood waters rapidly, as the rainfall in this district is torrential in its severity.

Reaching the summit, the engineers carried their alignment in a tangent down the side of a cone-shaped mountain, which stands out in solitary state from the main range. On this crumbling, rocky foothold the builders planted an angle station, where the line makes a sudden and sharp bend. A site had to be blasted out of



HOW THE HEAVY STEEL PARTS FOR THE PERMANENT WAY WERE TRANSPORTED BY NATIVES TO THE SITE OF ERECTION.

to the plateau, and clearing the sites for the supports. The upper station was selected at New Hornow, in close proximity to the saw-mill, while the lower terminus was placed at Mkumbara, $5\frac{1}{2}$ miles distant as the crow flies, and some 5,000 feet below, where the lumber could be trans-shipped to the surface railway for haulage to the point of shipment on the seaboard.

The precipitous character of the mountain slopes proved that abnormal gradients would have to be introduced, together with some huge spans. At first it was thought impossible to avoid spans of 6,600 feet, but closer investigation revealed strategical crags which could be used here and there, in order to bring the spans

the mountain side for the foundations, and this apparently simple problem teased the builders acutely, because the rock is friable, badly fissured, and slips alarmingly. Not until the engineers threw up a massive wall and filled in the crevices with concrete did they keep the treacherous mountain side in place. In this angle station are tension weights for keeping the lines tight. These weights comprise huge iron frames filled with concrete cubes. For the loaded rope there is a weight of 16 tons, with one of 13 tons for the unloaded rope. The ropes of the second division of the line are also anchored in this station. The traction rope of the upper division, however, passes on to that in the second section, being guided in the



LIFTING THE CABLES UPON THE SUPPORTS.

station by means of deflection and guide sheaves. Automatic working is not adopted, owing to the cheapness and abundance of the native labour, which need not be very skilled for this duty.

The descent from this station is extremely interesting because it is the steepest track in the world designed for continuous traffic. The grade is no less than 86.93 per cent., or 1 in 1.15. Moreover, in order to gain the next angle station it was found necessary to introduce two huge spans, each of 985 feet, and in one instance a lofty tower, approximately 100 feet in height, had to be erected to support the line.

Although the erection of the upper angle station offered some pretty puzzles, the difficulties encountered on the cone were insignificant in comparison with those

met in building the second station and the towers leading thereto. Six supports had to be placed at intervals of 33 feet, in order to lead the line into the station, and to place these towers the engineers reckoned that 70,000 cubic feet of earth would have to be shifted. The task was finished, and the engineer congratulated himself upon his success, until the rainy season came round. Then the mountain side began to slip and slide in all directions. Huge masses of rock and detritus came down, swept the towers away, and filled up the excavations. Work was resumed, but the landslips continued to be lively, and it was not until over 210,000 cubic feet of earth—three times the estimate—had been removed that the towers were permanently established.

The configuration of the country below



NATIVES STRAINING THE CABLE.

the second angle station is exceedingly rugged and broken, and the location of the line ranks as a masterly piece of engineering. The mountain side falls away sharply, forming a gaping ravine, which

bara Mountains before it reaches Mkumbara, where a raised platform has been provided, so that the heavy logs may be transferred direct from the cable-way into the railway cars.

Constructional work was beset with innumerable difficulties and searching questions, apart from those of a purely technical character. Labour was somewhat difficult to obtain, the local inhabitants being lazy and extremely primitive. By assiduous recruiting, however, more expert and diligent natives were brought in from outside territories. The natives had to act as porters, every ounce of material having to be transported from the railway terminus through the jungle, over circuitous paths and trails, to the points of erection. Timber was impossible as a constructional material owing to the ravages of the insatiable white ants. Consequently everything had to be wrought in steel. As far as possible all the parts were standardised and made interchangeable, to facilitate erection, while their weights and dimensions were kept within reasonable limits, to enable them to be carried by the natives over the rough and steeply ascending paths. The transportation of the ropes proved somewhat trying, inasmuch as these had to be carried intact. The general procedure was to uncoil the rope, and carry it in its long length upon the shoulders of the natives, a hundred or more being disposed in Indian file. In this way the ropes were carried to the stations, as if they were gigantic snakes, being transferred to the towers as the latter were passed during the march, and tightened by fifty to one hundred men tugging at the free extremity until the requisite tension was obtained. The most exasperating article to transport was a small locomobile required for the loading station. It was unloaded at the railway terminus and then hoisted, hauled, tugged and prised to the mountain top by the combined efforts of 100 natives and a



A TENSION STATION, SHOWING THE TOWERS WITH THE CONCRETE BLOCKS WHEREBY THE LINE IS KEPT TAUT.

slopes away finally to form the Panganis Plains. The engineers selected a favourable point on the opposite side of the gulch for their support, but 600 feet below, and 2,950 feet distant from the west cliff. Seeing that the floor of the ravine is several hundred feet below the trajectory of the aerial, intermediate supports were out of the question, so the engineers leapt the gulch in a single span, over half a mile in length. At this point a double tension appliance is introduced for the third section of the line, which descends to the plains, twice touching spurs of the Usam-

large staff of Europeans. A road was slashed through the jungle to permit it to pass, but progress was so slow that seven months elapsed before the engine reached the loading station, 5,000 feet above.

Another harassing feature accompanied the building of this short line through the air which recalled

the troubles experienced in carrying the railway through Uganda some years previously. The jungle is the home of ferocious man-eating lions, and these beasts, directly they found the forest trodden by the hundreds of natives passing to and fro, hung about these primitive highways on the look-out for juicy meals. Time after time a transport

train was thrown all sixes and sevens by these brutes. Gangs of natives would be trudging quietly and energetically forward with huge loads on their shoulders. Suddenly there would be a cry of alarm. Packs would be discarded hurriedly, and every man would plunge pell-mell into the forest to scale a friendly tree. At first the causes of such outbursts of excitement somewhat puzzled the engineers, but when they saw the shaggy head of old Leo gazing expectantly down the trail, they excused the apparent riot, and passed the tedium of the delay—the natives would never descend from their cyries until all signs of danger had vanished—by taking pot shots at the common enemy.

Seeing that the greater proportion of the

traffic is in the downward direction, and that the load on a carrier often represents two or three logs, 46 feet in length, and weighing a ton, special devices have had to be incorporated to check the descending speed, and to absorb all the power in excess of that required for moving the ascending light load. A special drive and



THE STEEPEST "BANK" ON THE LINE, HAVING A RISE OF 1 IN 1'15 = 65'53 PER CENT.

brake regulator was imperative. The line is driven by a 50 horse-power electric motor, capable of developing a high number of revolutions, with belt transmission to the driving shaft of the ropeway. There are two large band brakes, one of which, for security, is provided with a wooden-lined band, and a sheave about 78 inches in diameter fitted on the driving shaft. When stopping the line both these brakes, which together can neutralise 100 horse-power, are tightened, although during work they are disengaged, as the travelling speed is controlled by the brake regulator, so that human attention is unnecessary. The regulator is of the hydraulic type. It is driven by a belt from the counter-shaft, and consists primarily of a rotary



SAW-MILLS AND LOADING STATION AT NEW HORNOW ON THE USAMBARA PLATEAU.

pump and a balanced throttle slide. The former sucks the water from a reservoir in the foundation box of the apparatus and forces it back through the governing valve into the box. The governing valve is actuated by a centrifugal regulator driven by a belt. Directly the revolutions of the countershaft commence to increase, owing to the reduced strain on the line, the throttle slide closes correspondingly, and so checks the movement of the pump. The latter then acts on the shaft as a strong brake. A high-level reservoir of about 55 cubic feet capacity is placed above the loading station to keep the brake box regularly supplied with water, while there is also a low-level reservoir for use in the dry season, which is connected to the high-level reservoir by means of piping and a special pumping plant.

The cableway offers an easy means of gaining the heights of Usambara, which hitherto have been almost inaccessible. For official purposes there is a special

passenger car, but the majority of the employees and natives travelling over the line prefer the more unconventional method of riding astride a log. Certainly it offers the greatest thrill and sensation, especially when one is brought to an almost vertical position by the tipping of the log when making the bank of 1 in 1.15, or when flying across the gorge on the sagging span.

The erection of the railway was not void of humorous incident. A diverting experience is related by Herr O'Brian, who supervised the whole work. The towers had been completed, and he decided to make one final inspection before slinging the cables into place. He started off on a donkey and with three natives. They were jogging along quietly through the jungle, the engineer humming complacently, when suddenly the donkey reared, neighed viciously, ducked his head, throwing the engineer to the ground, and then plunged frantically into the jungle. Simul-

taneously the natives shrieked wildly and disappeared from sight. The engineer picked himself up, cherishing unkind thoughts about his asinine steed and attendants, and finally decided to climb a neighbouring tower to discover the cause of the turmoil. He had scarcely gained the tower top and was looking over the trees, when up popped the head of one native attendant on the next support in front, followed in a few minutes by the face of the second and third natives on the succeeding towers. The men retained their seats throughout the blazing hot day, suffering excruciating torment from mosquitoes, gnats, flies, and the heat. Late in the afternoon all descended from their perches and met upon the trail. The cause of the donkey's strange behaviour was revealed. It had sniffed the spoor of a lion which had passed that way several hours previously!

In order to receive warning of the whereabouts of these dreaded man-eaters the engineers profited from the cunning of the natives. A monkey will detect a prowling lion either by sight, hearing, or

smell with unerring accuracy, and gives vent to agonising, ear-piercing screeches. The natives catch and train the apes to act as warders of their safety. The engineers did likewise. They bartered and bought all the tame monkeys they could find, and then placed them in advantageous elevated positions, tethering them to the branches and fitting up a box as a residence. During the day the animal was constantly on the alert, and so perfect was the guard that very few men were lost from the depredations of the man-eaters.

Three years were occupied in the construction of this aerial ropeway, and by the time it was handed over to the concessionaires £75,000 had been expended. From the economic point of view it has undoubtedly proved a solution of the question how to transport the lumber from the Usambara plateau to the railway below, because in the first six months of its operation it handled 35,000 cubic feet of cedar. As an engineering achievement it ranks as one of the most interesting aerial railways which have been built.



THE UNLOADING STATION, WHERE THE LUMBER IS TRANSFERRED TO THE STEAM LOCOMOTIVE RAILWAY FOR HAULAGE TO THE COAST.

Showing tension weight tower.



Photograph supplied by the Caledonian Railway Co.

THE 10 A.M. GLASGOW-CARLISLE EXPRESS AT CRAWFORD.

Famous Expresses—III

THE CRACK CALEDONIAN "FLYERS" WHICH WORK THE SCOTTISH SECTION OF THE WEST COAST ROUTE



AS mentioned in a previous chapter, traffic between London and Scottish points, flowing over the West Coast route, runs via Carlisle. This city indicates the northernmost limit of the main line of the London and North Western Railway. Between the Border and Scottish points the trains are handled by the Caledonian Railway, a system which has achieved a unique fame from the expeditious working of the trains over difficult stretches of its system.

The express business of the main lines of the Caledonian Railway may be divided broadly into two classes. The first comprises the Scottish sections of the West Coast traffic, in conjunction with the London and North Western Railway; the second consists of the Caledonian express service proper between Glasgow, Edinburgh, Perth and Aberdeen.

The first named are represented by the up and down Scottish crack flyers of the West Coast route, or, as they are now known colloquially, "The White Trains," from the fact that the upper parts of the coaches are painted externally in white and gold. These trains are among the finest that this country can show in point of comfort, luxury, and up-to-date equipment. Six complete trains, composed of 57-foot corridor vehicles and 65-foot dining-cars, were built at the Wolverton works of the London and North Western Railway, and were first brought into the Scottish service in July, 1913, for the north and south bound morning flyers. The ordinary coaches weigh about 32 tons each, while the dining-cars are about 36 tons apiece unloaded, the total weight of a complete empty train being about 320 tons.

Taking the up trains first, the day express leaves Glasgow at 10.0 a.m. and Edinburgh

five minutes later. These trains run every day, Sundays excepted, throughout the year, although there is a slight modification in their operation according to the seasons. In the winter the Glasgow and Edinburgh sections meet at Carstairs, and run thence to London intact, but during the summer months they are run independently as far as Crewe, and from that point as one train to London. The number of coaches in each section is 10 from Glasgow, and 11 from Edinburgh, including through carriages from Glasgow to Bristol, Birmingham and London, and to Liverpool, Manchester, Bristol, Birmingham and London from Edinburgh.

The weight of each train upon leaving its Scottish stations is 328 and 356 tons respectively. They are handled by the heaviest type of superheated locomotives of the 4-6-0 class, which haul the load unaided over the Scottish sections. The scheduling over the 102½ miles between Glasgow and Carlisle, which is non-stop, except for a conditional call at Motherwell, is 132 minutes, while the Edinburgh portion makes the 100½ miles to the Border in 125 minutes, the average speed for the former coming out at 48.31, and for the latter at 50.25 miles an hour. Considering the trying nature of the road, and the heavy gradients, particularly the climb up the Beattock bank on the Glasgow line, where the summit is at 1,015 feet above sea level, the running performance is striking, and indicates the capacity of the powerful locomotives employed for the work.

The afternoon train leaving Glasgow at 2.0 p.m., while not putting up such high speeds, is also a notable flyer. The average composition of the train is nine coaches, representing a total unloaded weight of about 300 tons. It is likewise hauled by the "Cardean" 4-6-0 class of locomotive, covering the 102½ miles between Glasgow and Carlisle in 135 minutes—an average of 45.45 miles per hour.

In the reverse direction the 10.0 a.m. express out of London reaches Carlisle at 4 p.m., covering the 299 miles in 6 hours, an average of 49.83 miles per hour. Being the sister train to the 10 o'clock down, it runs daily, except Sundays, all the year round, is rostered with 10 coaches, representing an unloaded weight of 328 tons, and makes a non-stop run between Carlisle and Glasgow, except conditional calls at Symington and Motherwell. The distance between the Border and the Clyde city is made in 133 minutes, giving an average speed of 47.19 miles an hour. This run is made with the "Cardean" 4-6-0 type of locomotive, which has to fulfil some very hard work, especially upon the 10-mile climb between Beattock and Summit, where the grade ranges from 1 in 75 to 1 in 80. The 2.0 a.m. out of Euston, leaving Carlisle at 8.10 for Glasgow and Edinburgh, divides at Strawfrank Junction, the Glasgow section covering the 102½ miles in 130 minutes, including stops, and the Edinburgh portion making the 100½ miles in 140 minutes, the first-named maintaining an average speed throughout of 48.31 miles per hour.

In addition to the foregoing all-the-year-round daily expresses, some excellent performances are put up by the tourist expresses. The 7.45 p.m. out of Euston makes only two stops between London and Perth—at Crewe and Carlisle respectively. It runs daily—Saturdays and Sundays excepted—during July, August and September for the special conveyance of tourists. The rostered number of vehicles is six, but from the middle of July till the "Glorious Twelfth" it is always loaded to its uttermost capacity, is often duplicated, and at times triplicated, to cope with the heavy exodus created by the opening of the grouse season. As a rule it is worked as a non-stop between Carlisle and Perth by one of the superheated 4-4-0 class. The

**London-
Glasgow.**

**Glasgow
to Carlisle.**

**Tourist
Expresses.**



ONE OF THE FAMOUS CALEDONIAN
The 4-6-0 "Cardean" locomotives which handle these expresses between Carlisle, Glasgow and Edinburgh
feature of this



Photograph supplied by the Caledonian Railway Co.

FLYERS READY FOR ITS RUN.

are among the most powerful in the country, and ensure that punctuality which is such an outstanding well-known line.

train is scheduled to cover the 151 miles of the Scottish division from the Border in 175 minutes, which gives an hourly speed of 48.89 miles.

Fifteen minutes later the Perth and Aberdeen tourist sleeping saloon express leaves the Metropolis every night throughout the year, except on Saturdays during the summer months, and Saturday and Sunday nights during the remaining nine months. The Aberdeen complement averages six cars, but as frequently there are many additional special vehicles, the total unloaded weight of the train may be taken at well over 300 tons. During the height of the season the train is run in duplicate, the first portion of six vehicles being for Aberdeen only, and it runs from London to Carlisle with but two stops. Here a 4-4-0 locomotive is attached, and runs through to Aberdeen, 240 $\frac{3}{4}$ miles, with only one stop, at Perth, and a conditional call at Stonehaven. The 151 miles to Perth take 183 minutes, while the 89 $\frac{3}{4}$ miles thence to Aberdeen are covered in 113 minutes, giving average speeds of 49.5 and 47.74 miles per hour respectively.

As a matter of fact these records are far more remarkable than they appear on paper. The severity of the gradients is a great deterrent to high speed, because, in addition to the negotiation of the Beattock-Summit incline, the train has another pull against the collar for 5 miles from Bridge of Allan to Kinbuck, where the grade ranges from 1 in 73 $\frac{1}{4}$ to 1 in 100.

Possibly the finest speed achievement recorded by the Caledonian engines is the down Postal express, leaving London at 8.30 p.m. and Carlisle at 2.54 a.m. It is a daily train—except Saturdays—carrying through mail coaches for Aberdeen, Glasgow and Edinburgh, and totals 10 vehicles. The train is not advertised between London and Stirling, but becomes a passenger train from the latter point, owing to the attach-

ment of a passenger section from Glasgow for Perth and Aberdeen. The 299 miles between London and the Scottish border are made in 6 hours 48 minutes, while the 151 miles between Carlisle and Perth are reeled off in 179 minutes, representing an average of 51.98 miles per hour. The fastest speed, however, is made over the last section, the 90 miles between Perth and Aberdeen being notched in 97 minutes—55.51 miles per hour.

While the foregoing flyers worked by the Caledonian Railway are possibly the most familiar to long-distance travellers, the Caledonian The "Grampian Corridor" Express, expresses proper are great favourites among Scottish travellers. Pride of place is occupied by the "Grampian Corridor" dining-car express, running between Glasgow and Aberdeen. It is a non-stop between Glasgow and Perth, 63 miles, in both directions, making the distance in 82 minutes—an average of 46.1 miles per hour—while it covers the 89 $\frac{3}{4}$ miles between Perth and Aberdeen at 40.09 miles per hour.

The composition of the Glasgow portion is generally four 65-foot corridor coaches for Aberdeen, and five vehicles for Perth and Inverness. At Perth two 65-foot corridor coaches and a dining-car from Edinburgh are attached, together with a slip coach for Blairgowrie, which is dropped at Coupar-Angus. The weight of the "Grampian" cars varies from 35 to 38 tons per vehicle, so that the weight of the train leaving Glasgow is usually over 300 tons. On the return journey the load is about 60 tons heavier, owing to the addition of coaches from Dundee and Inverness at Perth. On the night homeward run, with this heavy load, the 4-6-0 superheated class of locomotive is called upon to perform some trying work. The gradients are particularly stiff, the heaviest being from Dunning Station to Gleneagles, where the gradient ranges from 1 in 89 to 1 in 121 for a distance of 7 miles. High speeds

are not possible, inasmuch as between Coatbridge and Glasgow the train has to traverse a division which is affected very considerably by mineral train working. On the outward run the train has to labour over the 5-mile pull from the Bridge of Allan to Kinbuck, and also has to overcome the Gleneagles bank, where the rail level reaches 401 feet above sea level.

The afternoon corridor express is another first-class train, comprising 10 vehicles similar to those of the "Grampian," bringing the total weight to well over 300 tons. It is a non-stop to Perth, where it meets the Edinburgh section, the first 63 miles with the 4-6-0 superheated locomotive being covered in 85 minutes, giving an average of 50.4 miles per hour. Thence the speed is not very high, owing to the number of intermediate calls which have to be made.

Then there are the residential expresses such as the "Strathearn," running between St. Fillans, Glasgow, and Edinburgh in the

morning, and between the latter two cities and Crieff in the afternoon; the "Stirling and Ben Ledi"; and the "Tinto," running between Moffat, Peebles, Glasgow, and Edinburgh. The "Strathearn" on the up journey makes an average of 38.85 miles per hour over the 68.125 miles between St. Fillans and Glasgow, with a maximum average of 45.72 miles per hour over the 57.525 miles between Glencagles and Glasgow and 46.08 miles per hour between Glencagles and Edinburgh. On the return journey the average speed is 41.12 miles per hour throughout. The "Stirling and Ben Ledi" express is an important residential train running between Glasgow and Callander, the 46 $\frac{1}{4}$ miles being covered in 78 minutes with six stops. The fastest run is made between Glasgow and Stirling, a non-stop for 30.125 miles, which is made in 40 minutes. This service is fulfilled by one of the Caledonian standard 4-4-0 bogie passenger locomotives.



Photograph supplied by the Caledonian Railway Co.

THE 2 P.M. GLASGOW-CARLISLE EXPRESS AT ABINGDON



DEFENDING THE CONSTRUCTION TRAIN AGAINST THE SPIRITED ATTACKS OF HOSTILE RED INDIANS.
An incident during the building of the first American transcontinental railway.

The First Railway Across the United States—I

THE EVOLUTION OF THE UNION PACIFIC RAILWAY



IN 1848 a tremor, having its genesis in California, ran round the world and agitated every nation from Scandinavia to Tasmania. Gold had been discovered! The effect was electrical. A gold fever of unparalleled virulence broke out; thousands anxious to get rich quickly by panning the Golden Fleece surged to the American seaboard, reaching their goal by devious ways.

Some braved the stormy passage around Cape Horn, others tramped across the Central American isthmus, taking to the high road which stretched northwards from Manzanillo, while still more "packed" the full breadth of the country.

The population of the State shot up by leaps and bounds. California sprang from oblivion into the full limelight of the world. Two years later it was admitted into the Union, having attained the dignity of



THE "OVERLAND LIMITED."

The crack train of the Union and Central Pacific Railways—the first American transcontinental—thundering through the Rockies.

statehood almost in record time. San Francisco assumed the style of City, though it was scarcely more than a straggling collection of shanties lining ragged, unkempt streets. Shops rose up, and the enterprising storekeepers drove a thriving

cussion of a sensational project. In the city was an engineering genius, Theodore D. Judah, a master of his craft, who cherished one great ambition. He had fallen a victim to the railway mania, and for a few years had been carrying out



By permission of the Union Pacific Railway Co.

"DRIVING THE LAST SPIKE." FROM THE PAINTING BY THOMAS MILL.

Connecting the Union and Central Pacific Railways at Promontory, Utah, May 10th, 1869, thus completing the first American Transcontinental Railway.

trade among the gold-seekers. There was the hardware shop of "Huntington and Hopkins" here, the dry goods store of "Crocker Brothers" there, and "Stanford's grocer's shop" just across the way. One and all of these respected citizens ultimately became millionaires, and powerful forces in their homeland. Did they make it out of ironmongery, wools and cottons, or sugar and tea? By no means, although the foundations of their fortunes might have been formed in their respective businesses.

The shops of these tradesmen were popular meeting places for the mutual dis-

unostentatious projects of this character in the State. He had succeeded beyond his wildest hopes, and, being sufficiently perspicacious, had voiced his opinion that a railway would be carried either over or through the Sierras, whose whitened tops frowned down upon the Golden Gate from the East. "A line through the Sierras!" Judah talked about it whenever he was drawn into discussion. The majority laughed at his dream, and chaffed him mercilessly for entertaining a thought about the vainly impossible. Now and again Judah was not to be found in his usual haunts; no one could give a word of

intelligence about him; he had disappeared. Suddenly he would be met in the Broadway or the saloon. His clothes showed that he had been tramping hard, and his conversation betrayed the fact that he had got the Sierras railway idea more fixedly on his brain than ever.

Still, while the greater number of the hare-brained gold-seekers and townfolk made light of Judah's pet theme, not so the ironmongers, the outfitters, and the grocer.

**The Traders
and the
Scheme.**

They listened attentively to his conversations, followed the results of his periodical excursions into the fastnesses of the Sierras—such were the periodical absences from the city—and when he stated that he had been right through the barrier and had penetrated into Nevada through a pass where a railway could be laid without any difficulty, their interest rose to fever heat. When Judah retired from the shops the tradesmen discussed his mad idea from a commercial point of view, and at last, like the engineer, became convinced of its feasibility. Among them was an astute journalist, the editor of a San Francisco paper, Cornelius Cole, and in due course he brought his influence to bear upon the theme.

The ironmongers, outfitters, grocer and journalist, together with a few other kindred spirits, at last decided to bring about the realisation of Judah's dream. But they recognised one point. It never could be accomplished by private enterprise. Government assistance must be invoked. Forthwith they approached the authorities, but received scant encouragement.

Meantime, in the East, a small body of enterprising men had been discussing a similar project, and they in turn memorialised the Government with similar success. But they were not dismayed by the cold official douche. Rival interests were driving home the cause of a Northern Pacific

**A Rival
Proposal.**

Railway. That was vetoed because it was not to go to San Francisco, and the advocates of the latter route threw themselves more vehemently into the central route as being the shortest and most direct across the breadth of the continent. They assailed the Government uncompromisingly and vigorously. One of the supporters of the scheme, Stephen A. Douglas, succeeded in introducing a Bill into Congress for the construction of a railway to the Pacific coast.

This forward step was more apparent than real. The project became the bone of bitter sectional dissension.

The scheme was debated con- **A National
Urgency.**

tinuously, it is true, but it did not advance one iota. The supporters of the transcontinental highway both in the East and the West grew more and more aggressive. Cole brought his pen to bear on the project and thundered away for all he was worth. Judah and the interested San Francisco tradespeople priming him with fuel for the campaign. In a short time it became more than a private venture; it blossomed into a national urgency.

This outbreak of energy had the desired result. A Bill was introduced and passed, authorising the construction of a "continuous railway of uniform width from the Missouri River to the Pacific Coast, so that cars might be run from one extreme end to the other." Although the task of construction was divided between two organisations, the Union and Central Pacific Railway Companies respectively, the two roads and branches were to "be operated and used for all purposes of communication, travel, and transportation, so far as the public and government are concerned, as one connected, continuous line." The Union Pacific was to advance westwards from the Missouri, and the Central Pacific eastwards from the Pacific coast, the two to meet and be connected on the California-Nevada inter-state line.

The Government recognised that the scheme was the biggest and most daring railway construction project which had been launched up to that time, and that it was beyond the powers of private initiative to fulfil, so extended tangible assistance. A

which stipulated that if the Missouri River were not in railway touch with the head of navigation on the Sacramento River by July 1st, 1876, then the whole of the completed portion of the lines, together with all rolling stock, material, land, etc.,



A GLIMPSE OF THE DOUBLE TRACKING NEAR KEARNEY, NEBRASKA.

Showing new automatic electric block safety signals. The cost of installing this signalling is approximately £300 per mile, while the cost of maintenance is about £30 per mile.

strip of territory through public lands 400 feet in width was granted for the right of way. In addition, 3,200 acres of land within a radius of 10 miles on either side were given to the companies for every mile of line. Financial aid was given in the form of bonds, payable in gold, to the extent of £3,200 per mile, except for 300 miles through the Rocky Mountains and the Sierras, where the subsidy was set at £9,600 per mile. The scheme received the assent of President Lincoln on July 1st, 1862, and was accepted by the respective promoters on June 27th, 1863.

The Government was determined on its part that the scheme should not suffer from procrastination nor become the sport of the stock markets. There was a clause

were to be forfeited to the United States Government.

The gauge, route, and the precise point of starting on the Missouri River were to be decided by the President of the United States. Congress, however, stipulated that the Baltimore and Ohio Railway should be taken as the standard for construction, and that the maximum grade and curvature were not to exceed those on the latter railway. Also, the first 100 miles of line were to be completed within two years of the Bill being accepted, and that 100 miles of line should be completed per annum thereafter.

Although the essential details were completed to general satisfaction, serious delay arose immediately. The question of gauge

had to be fixed. This appeared to be a trivial matter to determine, but as a matter of fact it assumed such proportions that drastic action had to be taken to

Union Pacific, seeing the possibilities of through running to the Atlantic coast, plumped for the standard gauge. On the other hand, the Californian legislature in-



THE BIG CUTTING ON THE LANE CUT-OFF.

This gigantic excavation is 5,300 feet long, 437 feet wide at the top, and 85 feet deep.

settle it. In the 'sixties gauges were all sixes and sevens. There was no cohesive working; no thoughts of through running powers. Great Britain had its broad and standard gauges; Continental Europe was similarly undecided; while in the United States there was even greater difference of opinion; each concern appeared to adopt the gauge which fancy dictated. The Erie and other lines had a gauge of 6 feet. Railways in Missouri had selected one of 5 feet 6 inches; while the Baltimore and Ohio, together with the Vanderbilt system, had adopted that of 4 feet 8½ inches—the standard British gauge. The

troduced a gauge of its own, differing completely from any other, namely, 5 feet. President Lincoln was asked to settle the difference of opinion, as time was slipping by. He found it an embarrassing duty, since he was certain to offend one company or the other. Ultimately he supported the Californians, impressed undoubtedly by the powerful interests in that state. So the 5 feet gauge was decided by him for both lines.

Instantly there was a hubbub. Two senators, favouring the Union Pacific's suggestion, and discovering the overwhelming preponderance of mileage of the standard



THE BIG PAPIO EMBANKMENT ON THE LANE CUT-OFF.

This improvement, 12 miles in length, cost £500,000, and saves 9 miles in distance.

gauge in the Eastern States, attacked the President's decision vehemently. California, supported by the President's decision in their favour, assumed an equally unbending attitude. Chaos reigned until the matter was taken out of the President's hands by Congress, and a Bill passed on March 2nd, 1863, fixing the gauge of the two lines and all branches at the standard.

As the Baltimore and Ohio Railway had been set down as a pattern to be copied, the builders of the transcontinental were at liberty to introduce grades running up to 116·2 feet per mile with a maximum curvature of 10 degrees—a radius of 573 feet. These were the irreducible minima to which the builders were compelled to agree, in order to earn the land grants and subsidies.

Now another hitch occurred on the Union Pacific. From what point was it to start on the Missouri River within the limit set down by Congress? **The Starting Point.** President controlled this situation, and he selected a point on the east bank known as Council Bluffs, opposite the present city of Omaha, as the terminal. Mr. Dey, chief engineer of construction, fell foul of this decision. He was an engineer; the President was not. The former preferred a crossing at Bellevue, which would give him an entrance to a natural path for the line, free from heavy grades or costly construction, which was unavoidable if the Presidential choice were followed. Besides, the engineer saw his way to save a few miles of line. He flouted the official selection and started work on his own location, completing grading to the extent of £20,000 before he was pulled up by the President executing a second decree reaffirming the point for the Missouri terminus at Omaha.

Even then Dey, the engineer, did not surrender to Presidential authority without a struggle. Two engineers were dispatched by New York financial interests to review the situation on the spot. They em-

phatically endorsed engineer Dey's selection at Bellevue, 7 miles south of Omaha, and the Government's engineer supported them. This overwhelming concurrence of opinion prompted the Union Pacific company to petition President Johnson for permission to modify the "Lincoln Location." The President investigated the matter disinterestedly, and, impressed by the surveyors' reports, granted the revision.

A terrible uproar ensued; the President unwittingly brought a hornet's nest about his ears. The citizens of Omaha, realising that they were to be left in the lurch, started what has been handed down to history as the "Bellevue Scare." **The "Bellevue Scare."** Monster petitions were got up, and an agitation which startled the country was fomented. The citizens adopted heroic measures for self-protection, and drove home their projects so powerfully, that the Johnson Revision was rescinded hurriedly, and the original Mud Creek route settled once and for all.

Several months were wasted in settling these preliminary disputes, so that it was not until December 2nd, 1863, that the first sod was turned on the Union Pacific Railroad, amid much jubilation. The Central Pacific Railroad, untrammelled by petty squabbles, after the gauge was decided, lost no time, the ground on that section having been broken nearly ten months previously, on February 22nd, 1863, at Sacramento.

But the Civil War threatened further disaster. Very little work was done on the Union Pacific Railway until the spring of 1865. The situation was precarious. Labour was **Effect of the War.** practically impossible during the years 1863-4, as every able-bodied man was engaged in that momentous struggle between the North and the South. All supplies had to be dragged overland from Des Moines, 140 miles away; from

Boonville, another distant railway terminus; or by a circuitous and slow river route confined to the summer months only. The whole of the route of the Union Pacific lay through country which was devoid practically of all constructional material except earth for the grade. The contracts called for the supply of 6,250,000 sleepers, and these had to be felled and cut in the forests of Pennsylvania, Michigan, or in the South, hundreds of miles away. Then 350,000 tons of iron rails and other metallic work were ordered, and with great difficulty got from the mills and hauled overland by oxen at a tremendous cost, and with galling uncertainty.

The plight of the contractors who had accepted sections upon carefully prepared estimates became alarming. Gold was at a premium of 50 per cent. Everything was at war level, and the contractors, unable to meet their obligations and finding their balances certain to come out on the wrong side, lost their credit. Although the Government had given such a liberal land grant and varied its gold subsidy from £3,200 to £9,600 per mile, according to location, private financial interests resolutely refused to advance a penny, declaring the Government's assistance to be unattractive and inadequate. The officials sought to enlist public assistance by means of stock subscriptions, but failed. Work was brought to a standstill almost, and remained dormant until the Government once more came to the assistance of the enterprise. The land grant was doubled, the railway company was permitted to issue first mortgage bonds equal to the Government's contribution, the latter, as a further inducement, agreeing to forgo its first lien upon the property. Furthermore, it enforced the surrender of a strip of ground, 200 feet wide, for the right-of-way through lands under private control or ownership.

The difficulties encountered, however,

were so disheartening that Mr. Dey, one of the most competent railway engineers of the time, retired from his position in 1865. Mr. Ainsworth assumed his mantle, and J. E. House was given complete charge of affairs in the field. This engineer ran the surveys through the Platte Valley, and accomplished his work so brilliantly that it has never been necessary to revise his location, which, even to-day, remains as one of the most perfect stretches of the system—so much so that it has received complete vindication by being double tracked.

Another peril and delaying influence was encountered when the engineers drew away from the confines of civilisation. The Civil War had left the Indians in supreme control

The Indian Peril.

of the plains, and they grew uncompromisingly aggressive and destructive. They disputed the advance of the railway builders resolutely. Vast hordes of red men hung about the track, pot-shotting the navvies, damaging the grade, and burning the depots whenever opportunity offered. There was no quarter; advance over every yard had to be fought sternly. One frontiersman, North by name, who knew the Indians and their warfare, threw in his lot with the railway builders. He raised a company of friendly Indians, and time after time pitched battles literally within sound of the whistle of the construction train were fought grimly. North never once failed to score on such occasions, and repeatedly drove the Indians away in great disorder. Subsequently the red men changed their tactics. Instead of concentrating their forces at certain points, they waged a guerilla warfare all along the line and wrought widespread havoc. Construction trains with supplies and provisions were held up, the navvies and trainmen taking cover on the vehicles or behind the wheels as they responded to the hostile fire. On other occasions running fights were waged for miles. It was not until



ROAD-BED BALLASTED WITH SHERMAN GRAVEL

This gives an excellent smooth and practically dustless road-bed. Analysis has shown that this gravel contains gold to the value of 8s. per ton.

the railway had drawn away from the plains into the foothills of the Rockies that peace was secured, and then only after the President had journeyed specially to meet the Indian chieftains around the camp-fire, and with *pow-wow* and peace pipe obtained an agreement securing immunity from further molestation, so that the navvies could throw themselves into their proper tasks whole-heartedly.

So far as the Central Pacific was concerned the difficulties encountered were only of a physical character, and although prodigious, were insignificant in comparison with human hostility on the plains. Judah had supreme control in the field, and he drove a wonderful location for those days, when money was scarce, through the mountains. He climbed the western slopes of the Sierras, following the courses of the torrent, seizing friendly shelter and crawling around steep precipices until he gained the summit level of 7,018 feet. In a similar way he descended the eastern flanks of the

range, crawling through gloomy canyons down to Truckee. Once the desert stretches of Nevada were gained construction advanced rapidly, and the pace was hot towards Salt Lake.

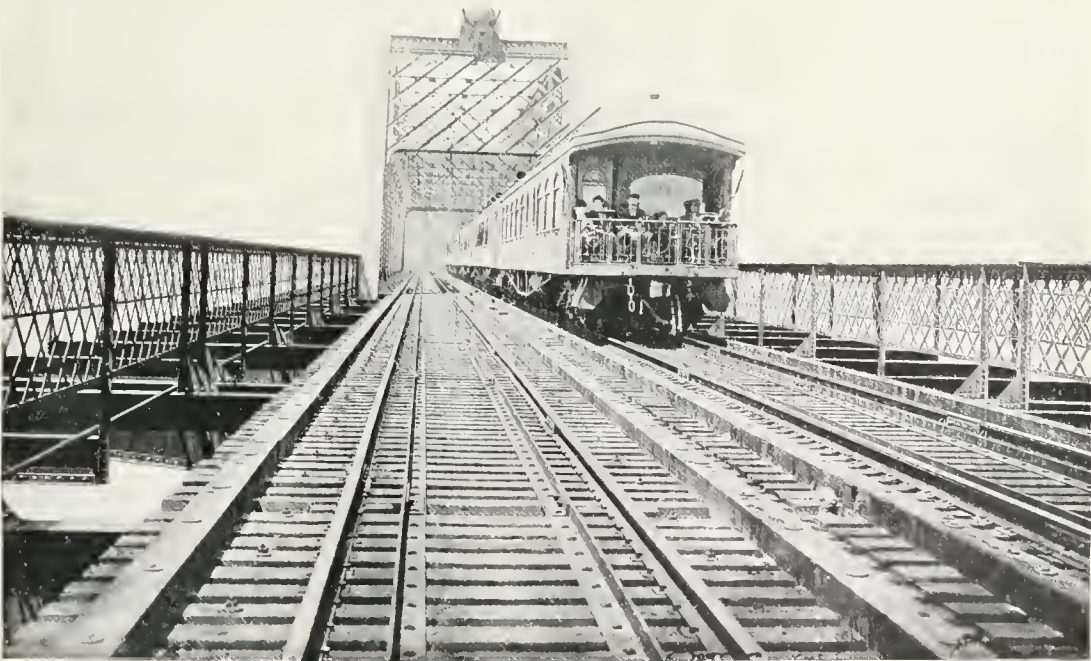
Despite the harassing difficulties on the Union Pacific section, General Dodge, who assumed the reins of engineer, kept things going in a marvellous manner. He was fortunate to be assisted by Dr. Durant, a born railway builder, who followed progress in the field, while Oake Ames, the contractor, performed prodigious achievements. Ames came upon the scene on August 16th, 1867, when the line had reached a point 247 miles beyond Omaha. The previous contractor went down in a financial disaster, but Ames took up the unfinished work, straightened out the tangle with wonderful rapidity, and by the skilful disposition of his navvying forces got construction into its stride, and went ahead at a record-breaking pace. In fact, at times the transport service failed to bring up supplies

with sufficient speed to keep his men going. Some idea of the energy with which Ames prosecuted his task may be gathered from the fact that in 633 days he tacked on another 839 miles, maintaining an average speed of about $1\frac{1}{4}$ miles per day in grade construction as far as Promontory, 1,086 miles from Omaha. In the year 1868 Ames built no less than 425 miles of line.

Yet the fulfilment of such a momentous enterprise as the first American trans-continental was not devoid of one strikingly humorous incident. The original charter granted to the Union Pacific Railway empowered construction from the Missouri River to the eastern boundary of the State of California, where the Central Pacific was to be met and junction between the two effected. Subsequently, however, this arrangement was modified, the Central Pacific being permitted to advance east-

wards until it met the Union Pacific. Accordingly there was a spirited race between the two forces, inasmuch as the Central Pacific was determined to earn as many acres of land grant and subsidy per mile as possible. This company set its eyes upon Salt Lake City, and resolved to carry its metals to that point by hook or by crook.

The two building armies, advancing from the east and the west respectively, met in western Utah during the winter of 1869. But they did not link up, as had been arranged. Instead, they raced past each other, building parallel lines, and pausing for nothing. In fact, each redoubled its efforts; it was a ludicrous situation, and strenuous efforts were made to stop this unexpected development. Congress met and discussed the junction arrangement, so as to force the two com-



THE ENTRANCE TO THE OVERLAND ROUTE: THE HUGE STEEL BRIDGE OVER THE MISSOURI RIVER CONNECTING COUNCIL BLUFFS WITH OMAHA.

The Bison's Head on the top is symbolical of the West.

panies to connect up. But the differences were settled between the rivals themselves, though not until the Union Pacific had laid its metal 225 miles beyond the point where it met the Central Pacific. Then, the railway companies realising the fatuity of this plan of campaign, the officials of the two concerns met in conclave and agreed mutually to make a junction at Promontory for the time being, until the matter was adjusted completely. Ultimately the Union Pacific yielded 50 miles of this last lap of 225 miles to its rival at a satisfactory price, the rest of the grade being abandoned.

The Golden Spike, offering through communication between the Missouri River and

the Pacific Coast, was driven on May 10th, 1869. The event, considered the third of importance in the history of the United States, was an occasion for national festivity, and was celebrated amid a display of fireworks worthy of comparison with the "Joyous Fourth of July." Exactly three years, six months, and ten days had been occupied on the task.

The decision that the Union Pacific should have its eastern terminus on the east bank of the Missouri River entailed the erection of a massive bridge in order to enter the city of Omaha. The forging of this link was entrusted to General Grenville M. Dodge.

He prepared his plans, and the company

was authorised to issue bonds to the extent of £500,000 to erect the bridge. A contract for the structure was made in 1868 for £217,900, but work was suspended a year later for some nine months, when a second contract was entered into with another bridge building company, bringing the cost up to £350,000. The bridge was built in eleven spans, each measuring 250 feet in length, with the rails 60 feet above high water. During the night of August 4th, 1877, the eastern end was wrecked by a cyclone. It was repaired temporarily, and answered all necessary purposes until 1886, when a new bridge, suited to modern requirements, was thrown across the river. The present structure is 1,750 feet in length and 56 feet 3 inches wide.



THE HOME OF THE UNION PACIFIC RAILWAY IN OMAHA.

This twelve-story skyscraper, housing a staff of 1,200, cost £300,000.



A BIG LOOP ON THE UGANDA RAILWAY TO OVERCOME A SUDDEN STEEP ASCENT.

Threading the Great Natural Zoo—II

THE WONDERFUL STORY OF THE UGANDA RAILWAY.

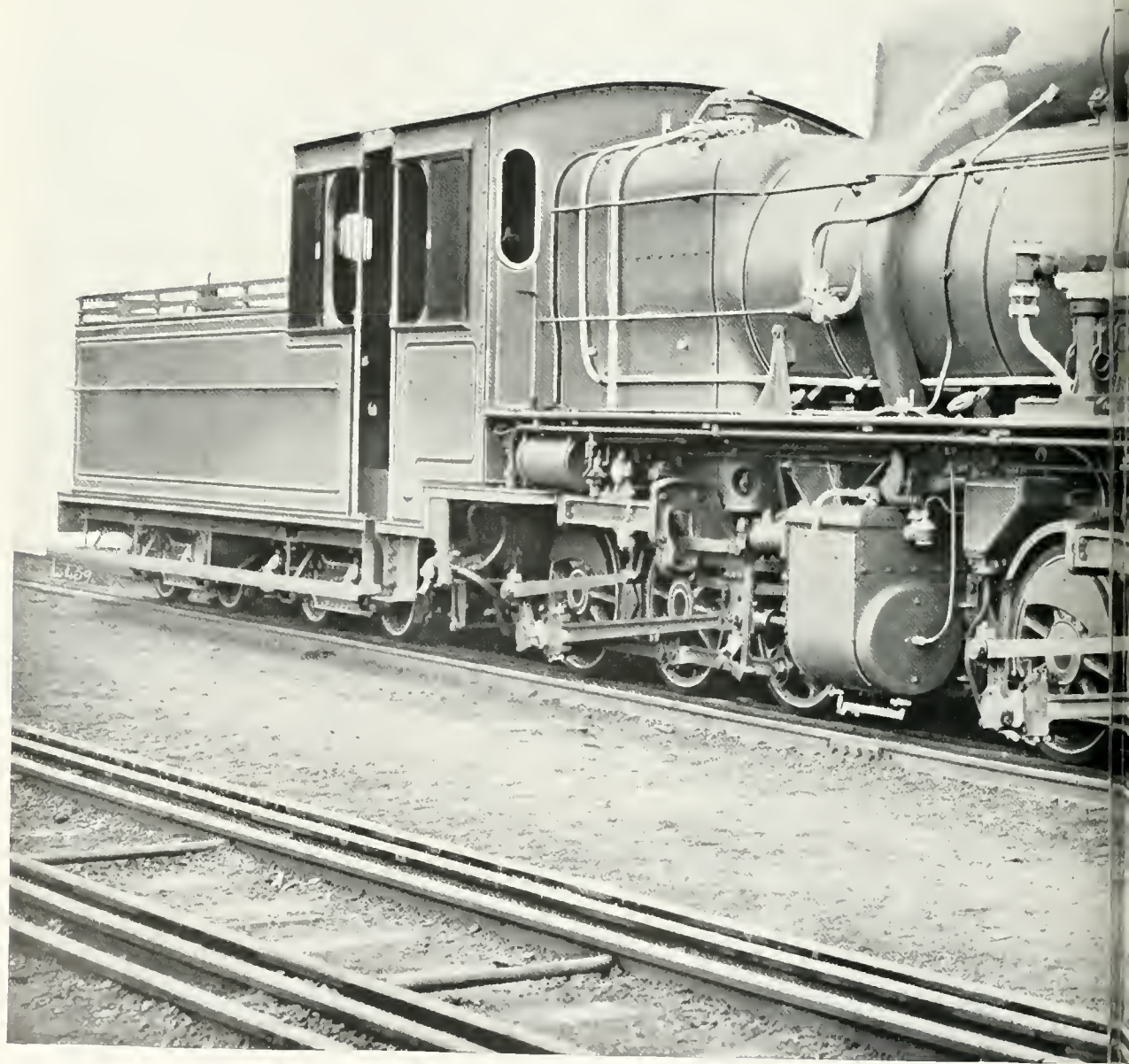


PUSHING out of Nairobi, the line continues to ascend until, after threading a dense forest, it comes apparently to the edge of a towering cliff, the Kikuyu Escarpment, at an elevation of 7,830 feet. Standing on the edge of the precipice, one gazes upon a wonderful panorama—the Great Rift Valley spread out some 2,000 feet below. When the engineers, in their ever upward climb from the coast, reached this point they made a pause. The ground falls away so rapidly—practically perpendicularly—into this great depression that the question of carrying an adhesion line into the valley appeared to be impossible.

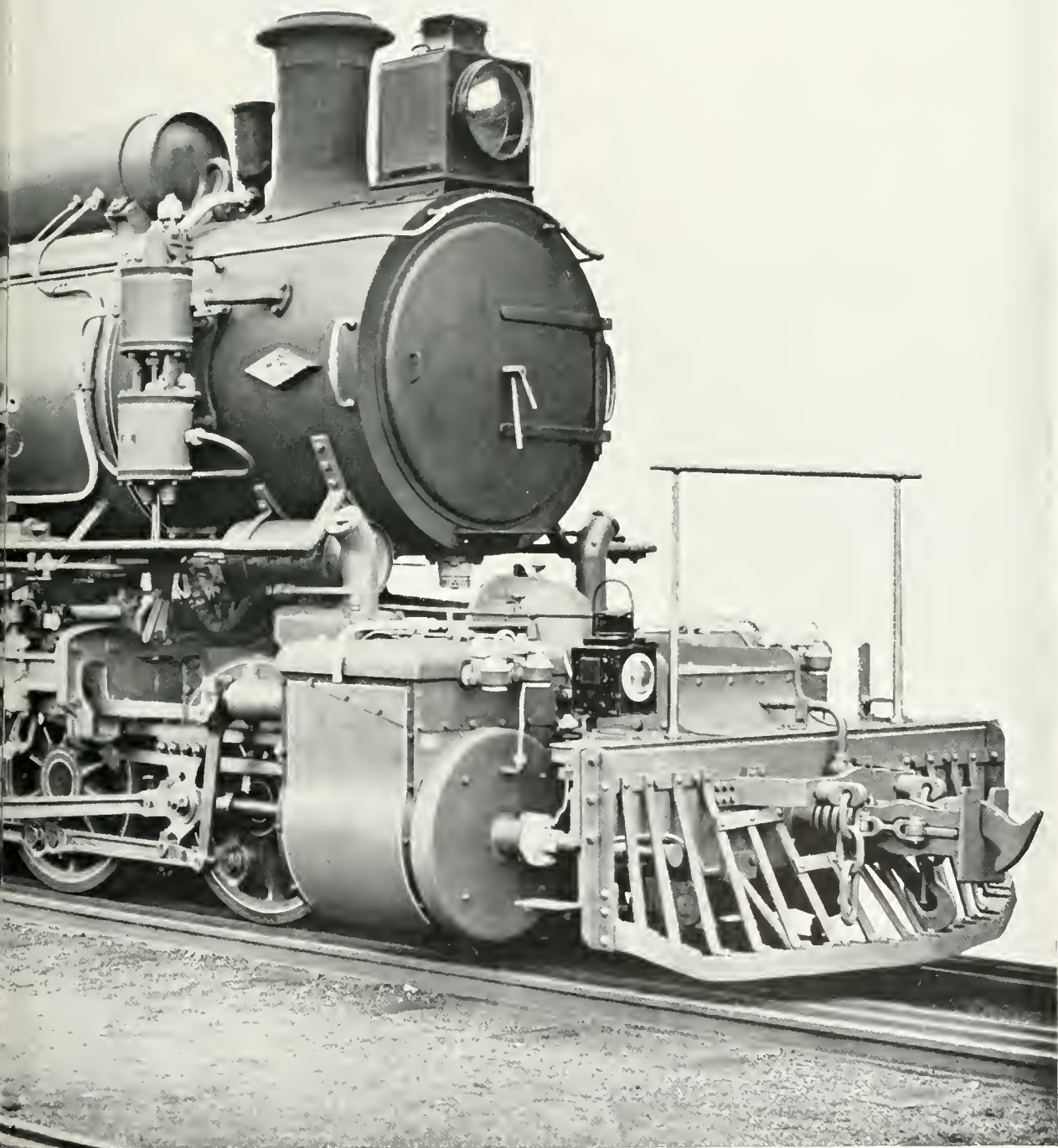
This was the first real technical difficulty

which was encountered so far as actual building was concerned, and the discovery of a method of taking the line down the cliff-side into the valley by means of a workable grade entailed the expenditure of considerable ingenious thought and the burning of much midnight oil. It brought the line to a standstill for the time being, but in order that work might proceed from the floor of the rift onwards, a rope incline was constructed to the summit of the cliff.

The engineers plotted and plodded the whole cliff from summit to base, and at last a means of overcoming it was discovered. The proposal was to carry the line down gently along a grade hewn out of the face of the precipice in order to gain



THE HEAVY 0-6-6-0 BRITISH-BUILT COMPOUND
The complete narrow gauge locomotive, ready for the road, weighs 91 tons 11 cwt.



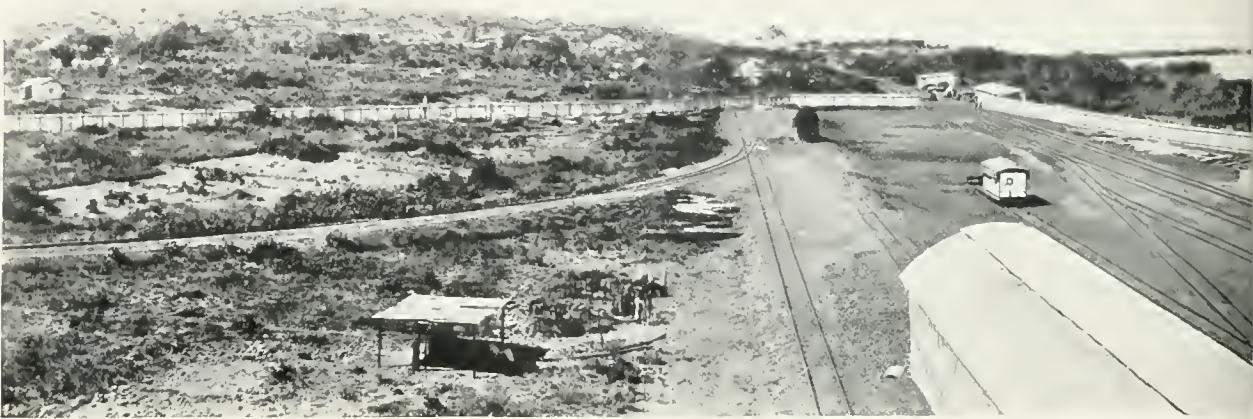
By permission of the North British Locomotive Co., Ltd.

MALLET IN SERVICE ON THE UGANDA RAILWAY.

It can haul a load of 170 tons up a gradient of 1 in 25 at 6 miles per hour.

a point 450 feet below. It involved a tortuous location, so that the descent might be worked by adhesion. But it was accomplished. The builders cut their way out of the cliff, hewing a shelf just wide enough to carry the track and no more, and describing marvellous twists and turns.

But the white engineers went ahead, despite the lugubrious prophecy, and, so far as they were concerned, they disproved it, because insignificant opposition was offered to their advance. The Masai regarded the steam engine with a kind of awe and extreme curiosity. No doubt they



PANORAMA OF PORT FLORENCE, THE UP-COUNTRY TERMINUS

The subjugation of this escarpment constitutes one of the finest illustrations in railway engineering skill that Africa can offer, and it becomes more striking when it is remembered that it is worked by adhesion without the introduction of switch-backs, V-switches, or other solutions which, although clever, handicap traffic.

After gaining the floor of the rift, another ascent commences through the Masai country. "For every mile of rails laid through the country of the Masai you will sacrifice the life of a white man." Such was the dictum of an eminent statesman who criticised the idea of building the Uganda Railway. It was not an idle warning by any means, because the Masai at that time were one of the most warlike African races, with their hand raised against every man and every man's hand raised against

were impressed by the railway builders' determination to thread their country at all hazards. To-day the Masai constitute one of the most stalwart guardians of the twin ribbons of steel, and are used for policing purposes, owing to some of the lesser tribes having nursed the impression that the railway is an excellent thing to loot.

After passing the station of Elburgon, 474 miles from the coast and 6,820 feet above sea-level, the ground becomes more rolling and broken, as well as threading dense forests, where the wood fuel required for the firing of the locomotives is obtained. The ground, falling away in all directions, is practically a series of successive big humps—through which heavy cuttings have been driven—intersected by deep ravines. The latter have been spanned by lofty steel

viaducts. The majority of these bridges are of American origin owing to the United States' bridge builders at that time being in a position to promise more rapid delivery and at lower prices than their British competitors. At the time there was a great outcry against the purchase of

through the only tunnel, 500 feet in length, though it is carried from hill to hill over the deep ravines by numerous steel viaducts.

The waters of Lake Nyanza are reached at Port Florence, where a prosperous town has grown around the terminus. By the



OF THE UGANDA RAILWAY, ON THE SHORES OF LAKE NYANZA.

American bridges with British money for a Government undertaking, but the main issue was the completion of the line in the shortest possible time. Under these circumstances the authorities were justified in their action. Still ascending, the railway at last reaches Mau Summit, the highest point, at an elevation of 8,350 feet, according to the bench-mark, 493 miles out of Mombasa. The uphill climb is long and tedious, as may be conceived, but the descent is almost as exacting, since in the course of 91 miles the railway has to drop 4,700 feet. In order to maintain the grade, the railway twists and turns in a bewildering manner, especially at Lumbwa, where a huge horse-shoe curve is introduced, an air-line alignment being found impossible. A few miles beyond Lumbwa, where rocky country is traversed, the railway passes

Uganda line the fresh and salt waters are brought within 584 miles of each other. The port, at an elevation of 3,650 feet, has a healthy situation, and is developing rapidly, owing to the growth of the steamship traffic upon the lake. These vessels, built in Great Britain, were shipped in pieces to the shores of this inland sea, where a shipyard was extemporised to permit of the reassembling of the parts. The first vessel was commissioned before the railway was built, and the sections had to be transported overland—an undertaking which offered a pretty problem to the engineer entrusted with the task; but the successive steamers were sent up in pieces over the railway.

By the time the shores of the Lake Nyanza were linked by rail to the seaboard £5,500,000 had been expended. Only

about half of this amount, however, went into actual work, the other half practically being spent upon freight. By the time the various materials were landed at Mombasa they had doubled in value.

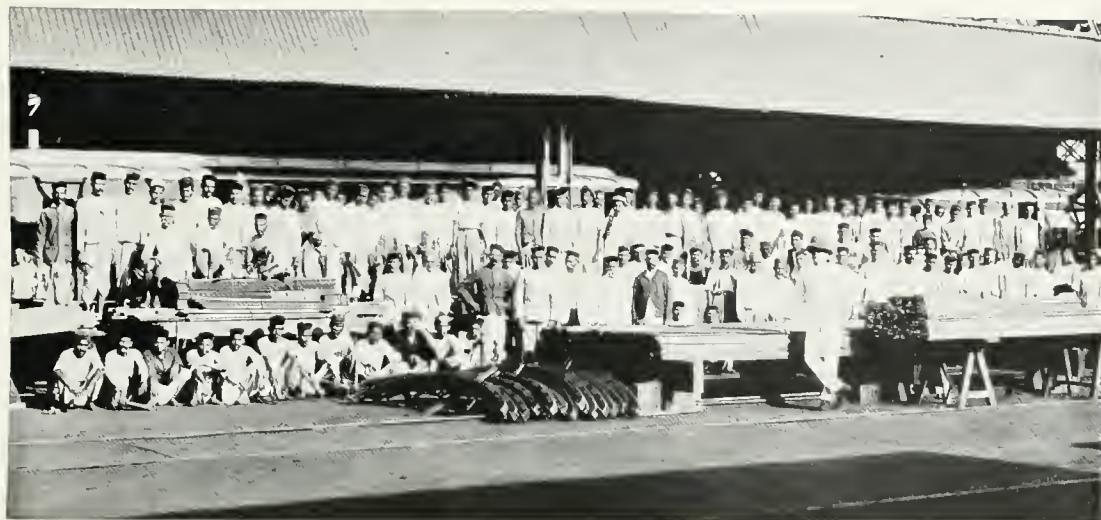
As may be recognised from the fact that the line has to climb to an altitude of 8,350 feet in the 491 miles out of Mombasa, westbound traffic—that is, imports—is costly to operate. But Uganda is such a promising and highly fertile country that within the course of a few years the export traffic should be in overwhelming preponderance. Seeing that the run to the coast for the greater part of the distance is downhill, the demand upon the locomotive effort in this case is not very heavy. Still, the westbound traffic is certain to be the heaviest for many years to come, and accordingly the railway has introduced the most powerful locomotive effort possible. The latest engine is an articulated compound 0-6-6-0 Mallet, built by the North British Locomotive Company, Limited, of Glasgow. This engine has been devised to haul a load of 170 tons up a long gradient of 1 in 25 at 6 miles, and a load of 200 tons up a bank of 1 in 40 at 12 miles per hour, and in each case round curves of 337 feet radius.

The locomotive has an over-all length of 62 feet 2½ inches, the total wheel base of engine and tender being 48 feet 7 inches. The forward low-pressure cylinders have a diameter of 24½ inches, while that of the high-pressure cylinders is 15½ inches, the stroke in each case being 20 inches. The driving wheels have a diameter of 39 inches. The rigid wheel base is 8 feet 3 inches; the total wheel base of engine 24 feet 3 inches. The boiler tubes have 1,398 square feet of heating surface, while that of the fire-box is 115 square feet, representing an aggregate heating surface of 1,513 square feet. The fire-grate area is 33 square feet. The working pressure of the steam is 180 pounds

per square inch. The weight of the engine in working order is 59 tons 17 cwt., the whole of which is available for adhesion. The tender has a water tank capacity of 2,000 gallons, with a fuel space of 270 cubic feet, and in loaded condition weighs 31 tons 14 cwt.—a total weight of 91 tons 11 cwt. for the complete locomotive.

From the financial point of view the railway has proved a unique success. Rates are comparatively low, the third class passenger, represented by the native, being carried for less than ½d. per mile, while goods are carried at about 2d. per ton-mile. The traffic upon the line has exceeded the most sanguine anticipations, and the results have astonished the most enthusiastic supporters of the enterprise. During 1910-11 the revenue aggregated £300,116, while the expenditure was only £201,596, leaving a surplus of £98,520, representing 1.6 per cent. The present service comprises four passenger trains per week in each direction, while the fares for the round journey between termini are £10 19s. return first class, and one half of this rate second class, representing about 2.25d. first class and 1.12d. second class, per mile. Sleeping-cars are provided, although passengers have to take their own bedding; and whilst refreshments are obtainable at certain stations, the passenger is wise if he stocks himself for the trip. The journey from Mombasa to the Lake occupies about forty-eight hours—a striking contrast to the four months' painful, weary and hazardous toil involved before the coming of the line. The construction of the Uganda Railway offers one of the most illuminating instances in the history of the railway in the complete subjugation of a hostile country, a great deal of which was *terra incognita*. In fact, so little was known about the land before the engineers arrived that while construction was in progress the surveyors were able to revise the route and to reduce the original location by about 100 miles.

**Success of
the Railway.**



THE NATIVE WORKMEN AND MATERIALS ASSEMBLED ON THE MONDAY MORNING

Building a Railway Carriage Against Time

AN INTERESTING RECORD ACHIEVED UPON THE GREAT INDIAN PENINSULA
RAILWAY WITH NATIVE WORKMEN



NOW and again a railway company, or a private organisation supplying necessities for the steelway, indulges in what may be described as a strenuous race against the clock in the performance of some particular undertaking. We have had a locomotive built in ten hours, a timber trestle $1\frac{1}{4}$ miles long run up in six weeks, and a steel bridge erected in a few hours or days, according to its dimensions. Such record-breaking achievements are only possible when the organisation of the particular concern is perfect, with men of the highest skill, and who appreciate the opportunity to let themselves go! At the same time, however, the countries in which such records can be put up are somewhat limited, being restricted

for the most part to the leading railways and concerns of Great Britain, and the United States, and Canada.

But occasionally the comparatively unskilled native, to whom the word "hustle" is unknown, and who, as a rule, cannot be induced to let himself go, is able to set up a performance which, if completed by the highly-skilled white man, would be regarded as distinctly meritorious. This fact was demonstrated very conclusively in the carriage-building works of the Great Indian Peninsula Railway, at Parel, Bombay, the organisation of which has been raised to an extremely high standard.

One day the operating department of this big railway found that it wanted urgently a standard 62-feet trailer coach for service with a small tank engine. The



THE RESULT OF THE SECOND DAY'S WORK.

discovery was made somewhat late, so, to meet the situation, a "rush order" was given. When this was received by Mr. A. M. Bell, M.I.M.E., the carriage and wagon superintendent, he resolved to treat it as an urgent requirement, and considered that it offered him a unique opportunity to test the organisation of his workshops and the capacity of his native workmen.

The superintendent was merely given the general indication of the type of vehicle required, and its projected service. The

and one other details. All the material for this vehicle came from some part of the British Empire. British steel formed the underframe: the framing of the body was fashioned from Burmah teak; while Australian wood sufficed for the greater part of the remaining woodwork.

By the end of 26 days everything was ready for actual erection. Every detail required was marshalled in the erecting yard, and all was left ready on the Saturday for commencing the task of building against



THE COACH AND THE NATIVES WHO BUILT IT IN 40 WORKING HOURS.

drawings first had to be prepared, and these were carried out at express speed. The requisition called for a two four-wheeled bogie coach with a steel underframe 60 feet long, giving the car an over-all length of 62 feet, by 9 feet 6 inches wide. Accommodation was to be provided for 6 first-class and 48 second-class passengers. In addition, there was to be a private compartment for 12 women, a luggage room, and guard's compartment.

While the drawings were under way, the orders for the necessary material were handed out to the different departments. The whole of the woodwork was prepared from the raw material, some 600 cubic feet of timber having to be cut, planed, and machined, to furnish 92 windows and shutters respectively, 19 doors, in addition to compartment partitions, roof-frames, roofing, walls, seat frames, and a hundred

time at 8.30 on the following Monday morning. The scope of the enterprise was explained to the native workmen, and they entered into the spirit of the test of their skill and organisation with keen zest. No overtime whatever was to be permitted; the men were to labour only during the usual eight-hour day.

At 8 o'clock on the Monday morning the men were assembled in the yard to receive their orders. There were 88 in all, under 8 native foremen or "maistries," with Mr. Bell himself supervising the undertaking in general. When the half-hour struck, the natives buckled into their task merrily. Although the working space necessarily was somewhat cramped, the division of the labour was so perfect that each gang was able to undertake its special duty without fouling or interrupting any other. Some of the gangs started upon the

framing, others took the floor in hand, while further gangs attacked the ends and sides. When work was knocked off at 4.30 in the afternoon the back of the job had been broken, and everything augured for a highly creditable performance.

The pace put up on the first day was maintained during the Tuesday. While gangs were hard at work on the actual body and framing, other bodies of workmen were engaged upon numerous other details. A crew of 66 carpenters, under 3 "maistries," set about the construction of the doors, windows, shutters, seats, etc., while 9 other men concentrated their energies upon the upholstery, blinds and other internal embellishments. By the end of the day the underframe was in position, the whole of the framework of the superstructure, including the roof, was completed, and the ends and sides had been placed.

During the Wednesday the whole of the woodwork was finished, while the steelwork was likewise completed. Hard on the heels of the carpenters came the painters, and during the Wednesday afternoon the vehicle received its first, or priming, coat of paint.

On the morning of the fourth day the coach received its final coat of paint, lettering, numbering and varnish. The electrical staff also completed the electric-light fittings, the vacuum brake was installed and adjusted, while all door handles, window catches, and other furniture were set in place. When the men ceased work for the day at the usual hour the coach was completed, and was ready for service, subject to the official inspection. This was carried out at 8 o'clock on the Saturday morning by the agent and deputy-agent, and then the coach was run out of the yard and handed over for service.

Thus the coach had been put through within a month of the receipt of the order by Mr. Bell. Actual erection had occupied only 40 hours. Although the work was "rushed," there was no undue speeding-up of the men, and the performance, rightly admitted to be a smart one, reflected considerable credit upon the efficiency of the Parel works and the completeness of Mr. Bell's organisation, while, at the same time, it afforded a very graphic illustration of what can be done with native labour under competent British supervision and instruction.



A CORRIDOR TRAIN ON THE SUBURBAN SERVICE OF THE GREAT INDIAN PENINSULA RAILWAY.



TRAIN OF 80 50-TON LOADED CARS (4,000 U.S. TONS) OF COAL EN ROUTE FROM THE ASSEMBLING YARD AT PRINCETON, WEST VIRGINIA, TO TIDEWATER, SEWALL'S POINT, VIRGINIA.

Cars may be loaded to 54 tons per car.

Unlocking a New Coalfield

HOW ONE MAN BUILT A 347-MILE TRUNK LINE TO RELEASE 6,000,000 TONS OF COAL A YEAR



WHEN the early American railways threw their tentacles into the eastern coal-producing territories, and thereby tapped new and profitable sources of revenue, one tract of country was studiously avoided. This was West Virginia. This vast territory is in reality one huge coalfield, extending over an area of 15,000 square miles, and with seams running up to several feet in thickness. But the rugged and ragged Alleghany Mountains locked it in completely from the sea. The country was as broken as could be found anywhere east of the Rockies, and every attempt to spy out a location favourable to the construction of a cheap line proved abortive. In view of the fact that a railway at least

300 miles in length would be required, it is not surprising that financiers shrank from providing the necessary sinews of war under such conditions. They preferred to back enterprises which penetrated to more readily accessible areas.

So the idea of building a railway between the coast and West Virginia languished. One or two mining organisations commenced operations and laid down short lengths of road hoping to worry their way through to the seaboard by some means or other, but they never proceeded very many miles.

At last one man appeared upon the scene and said that he would provide a railway, built upon the most up-to-date principles, and capable of reducing the cost of transportation to its lowest limits, at all hazards. No little speculation arose as to where the

money was to be raised, but the promoter of the enterprise did not allow that to stand in his way. He would finance it himself.

The man was Mr. Henry H. Rogers, one of the prime movers in the Standard Oil Company, and the colleague of John D. Rockefeller.

To gain some idea of what he proposed to do, conceive a new line run from, say, Carlisle to Brighton, only

What the Scheme Means. through a most mountainous country, such as Switzerland.

That was Rogers' dream. He went farther. He stipulated that east-bound traffic should not encounter a heavier rise than 10 feet per mile, while curves were to be reduced to the absolute minimum. He knew very little about engineering, but he did realise the fact that, unless he could carry coal more cheaply than any of his rivals running to competitive coal districts his enterprise would stand little chance of proving successful. He demanded as straight a line as could be laid down between the coal territory and the seaboard, over which a train of 80 cars, each containing 50 tons—representing a dead weight of 4,000 tons—could be moved. So far as the west-bound grade was concerned his restrictions were easier, as the banks would affect only the lightest traffic—i.e. the empties returning to the mines.

As a rule, when a new railway is projected, the promoters endeavour to link up as many important intermediate centres as possible, so as to tap sources of immediate traffic. But in this case Mr. Rogers merely gave the two extreme ends of the line—Princeton in the coal-producing area, and a point on the seaboard where he proposed to create a new, and his own, port. He merely told the surveyors to provide the shortest possible line between these two terminals consistent with his specification concerning grades, and he told them that they could roam the whole State if they desired to achieve this end.

The plotters ran over 5,000 miles of survey lines. At one time a first-class location was discovered, but when it was examined minutely **The Preliminary Survey.** it was found that, although it fulfilled all restrictions, it bore rather too far to the east, and that if a similar location could be found more to the west, where richer coal areas existed, it would do excellently. Once more the surveyors trod the passes, scaled the steep cliffs, threaded the narrow winding gullehes, and swam or rafted the swift streams and rivers intersecting the Alleghany Mountains. Obviously, they followed the line of least resistance as offered by the courses of the waterways as much as possible, but here and there the question arose as to whether it was cheaper and more advantageous to cling to such a natural pathway in preference to driving a special one through difficult country. For instance, at one point the waterway makes a big sweeping detour, describing almost a complete semi-circle. The engineers pointed out that by cutting across the chord of the arc formed by the river they could save 20 miles in distance, but that, owing to the heavy nature of the country to be traversed, the "cut-off" would cost £200,000 more to build than the easier and longer route along the waterway. Against this possible saving in constructional outlay the engineers placed the charges of operation and maintenance, and, figuring this upon a 5 per cent. basis, they found that although the first cost of the cut-off would be so much, yet from the operating and maintenance points of view a distinct economy would be possible, which in a short time would more than off-set the heavier initial expenditure. So the shorter and more difficult route was adopted.

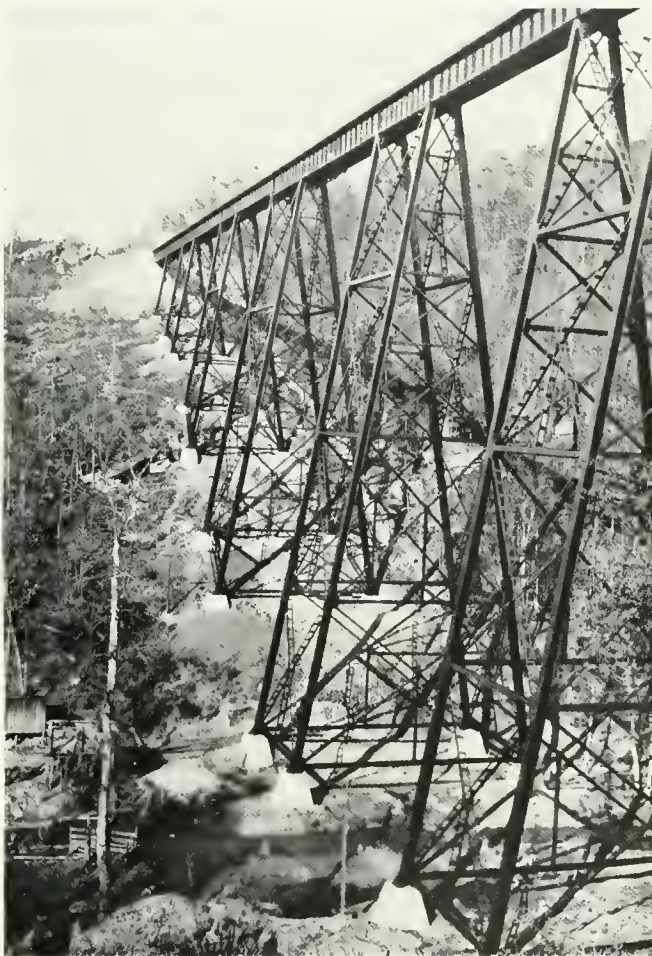
At some places the constructional cost came out far heavier than that incurred in driving any other American line, so that altogether the Virginian Railway ranks as one of the most expensive ever built

in the United States. The final location gave a length of 347 miles of line from Princeton, the inland terminus, to Sewall's Point, the tide-water terminal in Hampton Roads. They secured the requisite easy grade, except a short distance out of Princeton and a stretch of 14 miles between Elmore and Clark's Gap. Here it became necessary to make an ascent of 1,330 feet, with $11\frac{1}{2}$ miles of bank, having a continuous rise of 1 in 48, and a bank of $2\frac{1}{2}$ miles at 1 in 200, against eastward movement. On this section also they gave a minimum curvature of 495 feet. These adverse sections were absolutely impossible to avoid owing to the configuration of the country. But the remainder of the road complied rigidly with official restrictions. The banks varied between 6 and 10 feet per mile, and more than one-half of the total mileage is represented by tangents, with 9 miles as the longest stretch of one piece of straight. The curves varied from easy sweeps of 11,440 feet radius to sharp twists of 636 feet radius. Even tunnelling could not eliminate the latter, so they had to be retained, though all curvature in excess of 2,860 feet radius is spiralled and compensated.

As, however, the most difficult sections of the line came where the heaviest ruling grades could be bunched, they were admitted. Pusher services could be introduced to economical advantage, while the success of the articulated Mallet locomotive offered a complete solution of the problem for working the sharp curves which were brought into these sections. Although the Clark's Gap division is extremely heavy, necessitating resort to tremendous loco-

motive power in the form of Mallets weighing 376 tons, yet the stipulated minimum train loads of eighty 50-ton cars can be handled over the bank intact.

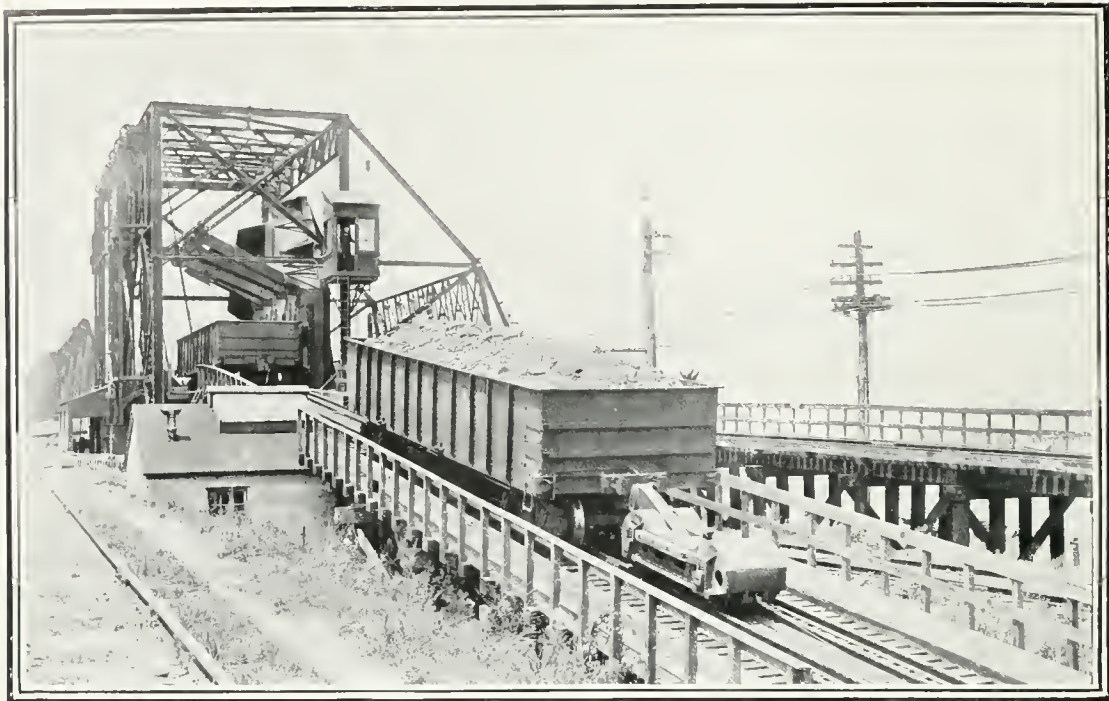
When the railway-builders arrived upon



THE BLACK LICK VIADUCT, THE HIGHEST ON THE LINE.

The rails are 207 feet above the water.

the grade they were confronted with problems every whit as teasing as those which had balked the railway plotters. There was a supreme tax upon the disintegrating forces of powerful explosives and the shifting capacity of huge steam shovels. Some of the excavation work reached huge proportions. At one point the line sweeps round the toe of a mountain shoulder where the wall of rock rises up sheer from the track, showing how the



A 50-TON CAR OF COAL BEING PUSHED UP THE INCLINE TO THE DUMPER.

navvies had to blast and tear their way down to the grade level. The spot has been nicknamed "The Palisades," and the description is apt. In driving a tangent through the mountains from a point known as Mullens, the builders had to throw up an embankment 125 feet in height, for which 140,000 cubic yards of soil were required, most of this being obtained from the adjacent tunnels driven through rocky spurs and shoulders. Even where the country proved somewhat kinder and a trifle easier, the track could not be laid without an average excavation of 60,000 and 70,000 cubic yards per mile. Some of the cuttings are as daring as the embankments and tunnels. Near Moneta there is one huge trench from which 260,000 cubic yards of soil had to be removed for a distance of 4,000 feet, while six miles beyond this work the excavation ran from 50,000 to 100,000 cubic yards per mile.

The deep rifts intersecting the mountain ridges, through which the streams and torrents make their way, were equally as exasperating, and had to be overcome by

extensive and costly bridges or by lofty viaducts. The highest structure of this character on the road is the Black Lick Viaduct, carried out in steel, with the rails 207 feet above the floor of the rift. The most striking bridge is the Glen Lyn, spanning the New River near mile-post 335. The river here describes a big bend, and is skirted by steep bluffs. In order to maintain the tangent whereby the waterway is approached, the engineers struck diagonally across the waterway and the low-lying opposite bank in order to gain a distant ridge. It involved a structure comprising a bridge over the main stream with viaduct approaches, 2,155 feet in length, with the rails 115 feet above the water. An easier crossing could have been made, but as it would have been adverse to the grade and curvature it was abandoned in favour of the straighter alignment. Altogether there are about 128 steel structures ranging from 8 to 2,155 feet in length, and representing an aggregate length of 34,508 feet, in addition to wooden trestles totalling 16,315 feet. The latter were introduced to save

time during construction, delays arising in the delivery of the steelwork, but they are being torn out and replaced in metal.

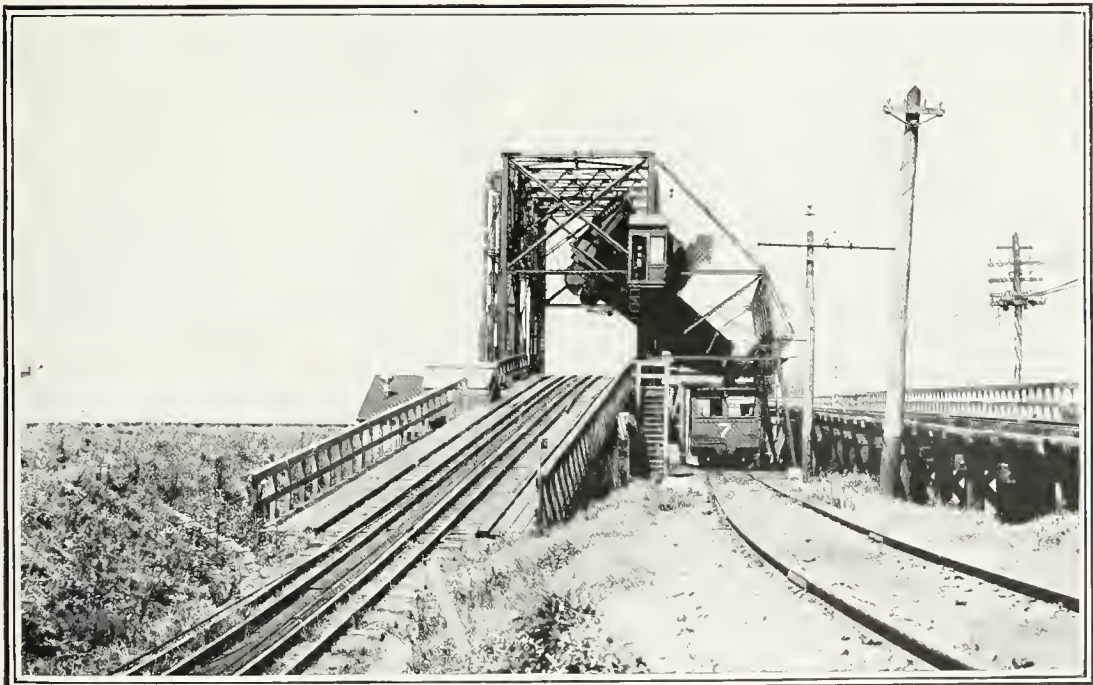
Tunnelling likewise is heavy. For the most part it consists of short drives through projecting spurs and ridges. The longest and most important work of this class is that whereby Clark's Gap is crossed. This is 1,205 feet in length. Nearly all the tunnels are bored through solid rock.

At Princeton extensive sidings have been laid down, as this is the point where coal trains which come in over the spurs extending to collieries in the district are marshalled preparatory to the long direct haul to the coast. There are 17 sidings in all, aggregating 11·7 miles, capable of receiving 1,288 coal cars, though the accommodation is being extended for 1,400 trucks.

In selecting a seaboard terminal the guiding spirit resolved to create his own facilities, and in such a way that he would possess ample elbow room to meet future developments and expansions. So his

engineers made a minute investigation of the south shore forming the well-known Hampton Roads in Chesapeake Bay. Ultimately they decided upon a stretch of sandy beach on the bank facing Newport News, but slightly nearer Cape Henry.

On this stretch of land a special coal unloading pier has been erected, so that vessels may come alongside and receive the coal direct from the railway cars. The pier is one of the best-equipped plants of its character in the world, and cost £400,000. Sewall's Point, as the terminus is called, a decade ago was a desolate, bleak and unvisited spot, to-day it is one of the busiest corners of the lower harbour. In order to reach the pier the engineers had to reclaim a large stretch of ground, which was accomplished by throwing up massive retaining walls. The idea was to select as deep water as possible for mooring purposes, and the wisdom of this selection is reflected in the fact that the pier now works continuously throughout the 24 hours, the pilotage association having sanctioned the



THE DUMPER AT WORK.

The road-car being turned over, emptying the 50 tons of coal into the pier wagon.

movement of vessels to and from the pier by night as well as by day. The pier, which is of timber, is 1,045 feet in length, provided with enormous hoppers and shoots whereby the coal is discharged direct into the holds of vessels. At the top it is about 65 feet in width, and carries three railway tracks—two delivery and one in the centre acting as a gravity return. At the water end the rails are about 70 feet above high water, by 78 feet at the shore end. At the shore end of the pier there are sidings capable of receiving 185 laden trucks, and by means of the mechanical devices with which the pier is equipped 15,000 tons of coal can be shipped during the 24-hour day. Vessels can berth on each side of the structure, there being accommodation for eight craft 200 feet long, or four ships 430 feet in length.

Seeing that the Virginian Railway depends for its very existence upon the amount of coal which it can pass from the collieries to vessels, every conceivable device for accelerating the discharge of the fuel has been adopted. When a train carrying 100 car-loads of coal, representing a dead load of 5,400 tons, is able to pass over the road, it will be seen that everything depends upon the celerity with which the trucks can be emptied and cleared out of the receiving yard. The railway cars do not run out on to the pier itself, but their loads are transferred to a special pier car, and, in order to expedite and facilitate this part of the work, what is known as a "car-dumper" has been introduced.

The shunting engine backs the loaded railway cars on to allotted tracks according to classification. Then a number of cars are pulled out of their siding, and placed in what is known as the "barney yard," which is contiguous to the pier. Here the cars, one at a time, run down by gravity to the bottom of an incline to be engaged by an electrically-operated barney hoist, and taken up the incline to the car-dumper.

This is a steel tower, on to the upper platform of which the laden truck is run. After being made fast it is turned bodily over, so that its contents are discharged into the pier car, which is upon a lower track alongside, the coal falling down over a deflecting steel apron so that it may not be damaged unduly in the operation. The pier car is able to receive the full load—50 tons—of the railway wagon. In turning the railway truck completely upside down the whole of the contents are discharged, and the car itself afterwards is delivered in its normal position upon the lower track of the car-dumper. It stands there until the next vehicle is emptied in a similar manner, when the empty wagon receives a mechanical kick to be sent down an incline into the empty yard, where the return trains for Princeton are marshalled.

The pier car, having received its load, runs by gravity on to a platform, where the net weight of the load is recorded automatically. Then the vehicle runs down a slight incline to the bottom of the hump leading to the pier. Here it is engaged with an electrically-operated barney hoist, and pulled up the 1 in 4 bank to the pier top. Disengaged, the car commences to run along the pier by gravity, until it is spotted by one of the men, who, recognising for which vessel or hopper the load is intended, allows the vehicle to continue its way until it is opposite the desired spot, when, by the manipulation of the air-brake, the car is stopped, and at once discharged by opening the air-controlled hopper bottom. The coal falls through the floor of the truck into the 60-ton hopper and through the adjustable chute into the vessel's hold. Emptied, the car passes on to the central return gravity track back to the dumper to await a fresh load. The control of these cars is of a perfect character, each being fitted with electrical, pneumatic, and mechanical devices to achieve the desired end with the utmost celerity. There are ten

How the Coal is Dealt With.

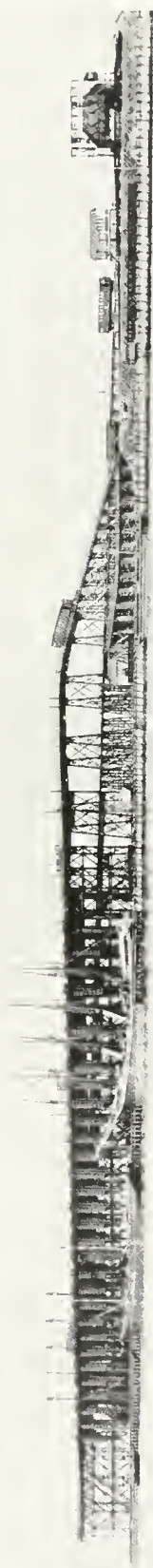
Unloading the Cars.

pier ears in all, five of which are normally in service, and in this manner it is possible to empty 30 railway trucks per hour—one every two minutes—representing in all about 1,500 tons.

The Virginian Railway is essentially a coal-carrying line, and was built expressly for this work. Passengers are almost unknown: they form only $5\frac{1}{2}$ per cent. of the total revenue. The total number of passenger vehicles in service three years after the opening of the line was only 40, as compared with 6,409 freight cars, of which total 4,966, including 2,997 gondola vehicles, were for coal only. The road was opened from terminus to terminus on July 1st, 1909.

The development of the new coal country directly it was provided with an outlet to the sea, as represented by 347 miles of single line, was amazing. In 1910 the company gave orders for the delivery of 2,000 50-ton steel ears and 32 locomotives, but a year later the business had grown to such proportions that this stock proved to be totally inadequate, so a further 1,000 vehicles of the same type were bought, together with some 14 massive freight engines. The locomotives from the very beginning have created attention from their size and power, heavy Mikados being used for the road, and massive Mallets for the pusher service over Clark's Gap. The latest mammoths for this work are described in another chapter.

The forging of this railway link has stimulated the output of existing mines and the laying out of new works to a remarkable degree. It is estimated that the railway and its branches tap 4,000,000,000 tons of coal—sufficient for 400 years, if 10,000,000 tons per annum are shipped. One colliery, before the coming of a branch into its territory, could only work three days a week, owing to the difficulties of transporting the fuel to the nearest station upon the railway. Directly the spur was completed the mine settled into its stride



THE TIDEWATER TERMINUS OF THE VIRGINIAN RAILWAY, SHOWING TIMBER PIER: A CAR WITH ITS 50 TONS OF COAL IS ASCENDING FROM THE DUMPER TO DISCHARGE INTO A VESSEL LYING ALONGSIDE.

and in the first ten months delivered 45,000 tons of coal to the railway. Another group which was in a similar quandary was provided with a branch, and within the follow-

of hemlock forest, roamed by bear and deer, where the only inhabitants were hunters in the spring of 1909. Then came a company to exploit the dormant coal wealth.

Ten months after the first swing of an axe to level the forest, 42,000 tons were put out in the course of a month. To-day the forest of four years ago is a prosperous mining town, with a theatre, and many other conveniences which older communities still lack.

The whole of this traffic flows along the steel channel of the Virginian Railway, and development and expansion are proceeding so rapidly that before many years have passed this line will rank as one of the greatest coal roads upon the continent. Other industries are opening up in all directions, necessitating the laying down of branch lines which radiate from the main road like big ribs, while towns are springing up along the track with astonishing speed. This movement had been anticipated; permanent commodious stations had been provided at all attractive points in readiness for the business which is bound to come.

Few railways have had such a marvellous and rapid growth as the Virginian, the prosperity of which is due entirely to the perspicacity and daring of one man—Henry H.

Rogers. He had it built in accordance with his ideas, and found every penny for construction out of his own pocket. To-day the line is in a position to move over 6,000,000 tons of coal per year, while in the near future its annual capacity will be about 10,000,000 tons.



"THE PALISADES."

In order to preserve the gradient heavy side-hill excavation was unavoidable.

ing 21 months turned over 435,911 tons of coal for haulage to the coast. A third mine is shipping 400,000 tons per year, while another is turning out 100,000 tons per month, and before long will add another 75,000 tons monthly to this total. At a point known as Tams was a stretch



THE MIDLAND SCOTCH EXPRESS TRAVERSING THE PICTURESQUE COUNTRY
OF THE DALES.



Photograph supplied by the Midland Railway Co.

THE TRENT VIADUCT AND REDHILL TUNNEL.
Showing the castellated portal.

The Waverley Way to the North

THE STORY OF THE MIDLAND RAILWAY



OF the three trunk roads which connect London with Scotland the story of none, perhaps, is so fascinating as that which is known to-day as the Midland Railway. Its birth was humble; for years it confined its operations to the development of the country immediately contiguous to the scene of its origin; it became associated with one of the most notorious figures in the history of high and frenzied finance and railway aggrandisement, and finally emerged into one of the most progressive and prosperous railways of the world.

In the early days of the nineteenth century the coalfields of Leicestershire were sorely handicapped by the absence of cheap and expeditious transportation facilities. True there was the Charnwood

Forest Canal, extending to the county city, but it was an uncertain highway. In winter movement was held up by frost and ice, and when the waterway finally burst things were reduced to a critical condition. The city suffered severely from the dearth of fuel, but its loss was trivial in comparison with that of the collieries, which were deprived of their ways and means of disposing of their produce.

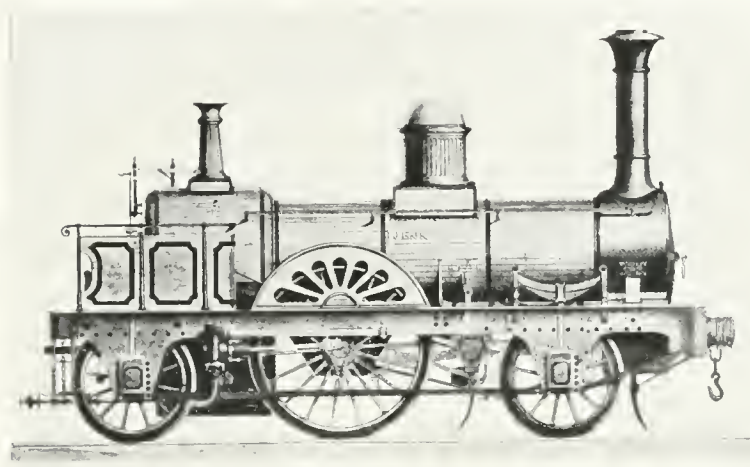
It is an ill wind which blows nobody good. Leicestershire's disaster was the opportunity for the rival coal producing country of Derbyshire and Nottingham. The collieries in the latter county did not let slip the chance to forge ahead, to the detriment of the Leicestershire fields.

This state of affairs became so intolerable that one or two prominent figures in the Leicestershire colliery industry conceived a bold master-stroke. One, William

Stenson, was particularly enterprising and aggressive. He had watched the progress of George Stephenson's invention, and had followed the building of the Liverpool and Manchester Railway with the liveliest interest. If a steelway could benefit the two great cities of Lancashire, surely it

communicated with George Stephenson, who at that time was wrestling with the problems involved in the building of the Lancashire Railway. Stephenson's services at that time were in urgent request the whole world over, and so he declined to become associated with the Leicestershire project.

But Ellis was not to be thwarted. He invited the Father of Railways to a bumping dinner, which proved so satisfactory that the eminent inventor was induced to reconsider his refusal. He promised to go over the country with Stenson's surveys so as to become acquainted with the situation at close quarters. He did so, and reported so favourably upon the project that he even undertook to



THE "JENNY LIND."

An early type of the single driver locomotive.

would prove equally useful to the Leicestershire coal districts. Why not lay down a railway for the transportation of the fuel to the nearest and most remunerative market? To him there was no valid reason why it should not be done. But fearing that such a suggestion might be scouted as wildly impracticable by ignorant and prejudiced interests, he decided to investigate the question personally and unaided, so as to fortify himself with facts, figures, and massailable arguments when the moment arrived for its discussion.

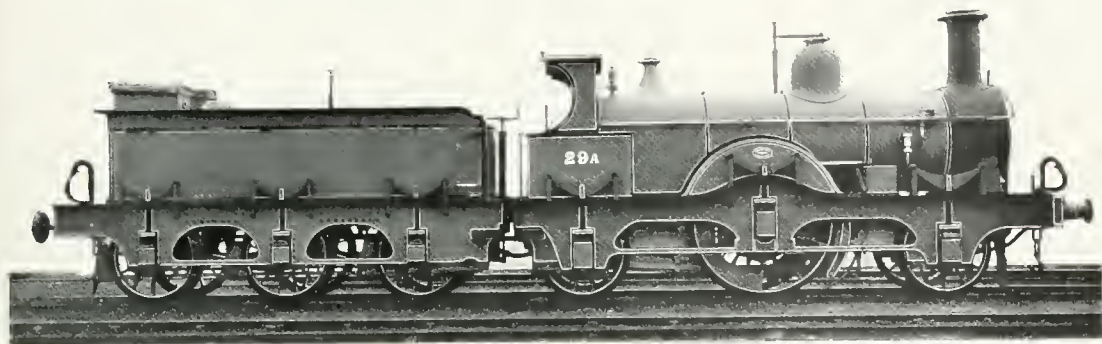
Armed with a level he made a hurried run through the country between Swannington and Leicester, and this rough survey convinced him more than ever that his idea was perfectly feasible. He thereupon unfolded his proposals to a kindred spirit, Mr. John Ellis, who at once saw eye to eye with the scheme, and in order to secure the very highest possible recommendation in its favour he com-

raised the money to defray the cost of construction if necessary. As, however, his hands were so full with other plans for railway conquest he pointed out that he could not supervise construction, but strongly recommended that his son, Robert, who had been called home from South America, should be appointed engineer-in-chief, since the Manchester and Liverpool Railway was practically completed.

Parliamentary sanction for the construction of the Leicester and Swannington Railway, as it was called, was extended in 1830. It was not a big enterprise as railways go, being only sixteen miles in length, but it involved some problems which in those days were by no means so simple to solve as now. The Glenfield Tunnel tripped up the contractors badly. It is perfectly straight, level, and 1,796 yards in length, but it extends through running sand. Boring for a single line of standard

gauge was commenced from either side of the hill to be pierced, as well as in both directions from the bottom of four intermediate shafts. Keeping the sand back became the supreme difficulty, involving

investigation without bearing sad evidences of the ordeal. The fathers of this scheme, the "Midland Counties," found out very quickly that it is very easy to tread heavily upon the toes of others in railway matters.



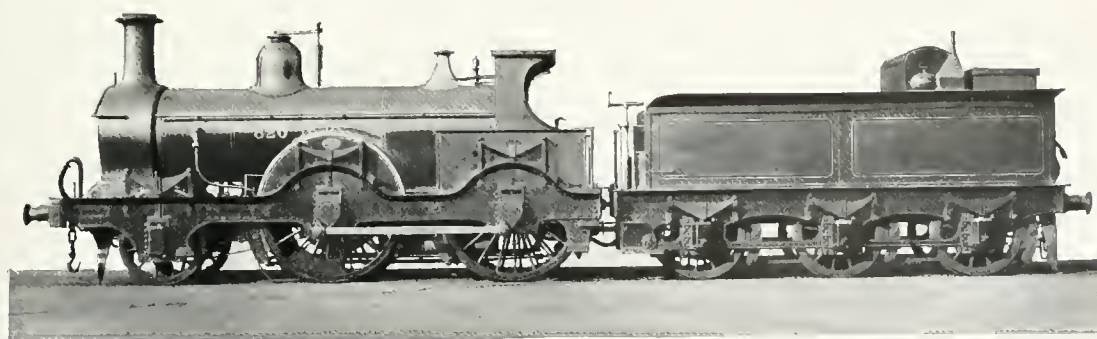
Photograph supplied by the Midland Railway Co.
LATER TYPE OF THE "SINGLE DRIVERS"—BUILT JUNE, 1865.

heavy timbering in advance of the brick-work lining. Even then progress was so slow that finally the contractors threw up the job in disgust, and retired from the scene broken in finance. The troubles experienced in connection with the Glenfield Tunnel having been noised far and wide, no one could be tempted to essay the task, so the railway company was forced to complete it by direct labour.

The opening of this short line solved the coal transportation problem for Leicester-

and so encountered such relentless opposition that the dreams of railway conquest had to undergo modification. However, the foundations of the future prosperity of Derby as a railway centre were laid by linking it with Leicestershire in 1840, as well as throwing out spurs to Rugby and Nottingham.

Another system was the Birmingham and Derby, carried out between these two points by George Stephenson, while the "North Midland" was projected by the



Photograph supplied by the Midland Railway Co.
LOCOMOTIVE NO. 820: REMARKABLE FOR ITS HEAVY OUTSIDE FRAME.

shire very effectively, but to the disadvantage of the Nottingham coal interests. The latter thereupon embarked upon a comprehensive scheme of retaliation. But its proposal did not emerge from Parliamentary

same engineer to provide a railway route between Derby and Leeds. In this work Stephenson had a pretty stiff tussle with the treacherous shale when driving the Ambergate Tunnel.

The completion of the "North Midland" and the "Derby and Birmingham" lines precipitated a result which was somewhat common in the early railway days, when roads were run to competitive points, and which, while beneficial to the travelling public, affected the shareholders some-

it was associated the man who had undertaken the chairmanship of the amalgamated concerns—George Hudson. From his astute tactics, many of which were of a doubtful character, he became the first Railway King, the Harriman of the Forties. He secured control over 1,000 miles of lines,



Photograph supplied by the Midland Railway Co.

THE AMERICAN TYPE OF PULLMAN CAR WHICH WAS INTRODUCED UPON THE MIDLAND RAILWAY IN 1874.

The first vehicle was built at Pullman City (U.S.A.), shipped in sections to Derby, and there re-erected.

what adversely. Both lines were able to give and take traffic from the London and North Western Railway as it is now. Both fought hard for this business. The competition produced a rate war, with fares and tariffs cut mercilessly. This condition of affairs prevailed until at last, additional competition being threatened from new construction, the rivals awoke to the fact that if further lines were completed the traffic would be divided still more, and they decided that it was better to combine forces. Accordingly a permanent peace was secured in an effective manner—the opposing factions amalgamated and blossomed forth as "The Midland Railway," with a combined mileage of 181½ miles, on May 10th, 1844.

Then the railway speculating mania broke out with fearful virulence. With

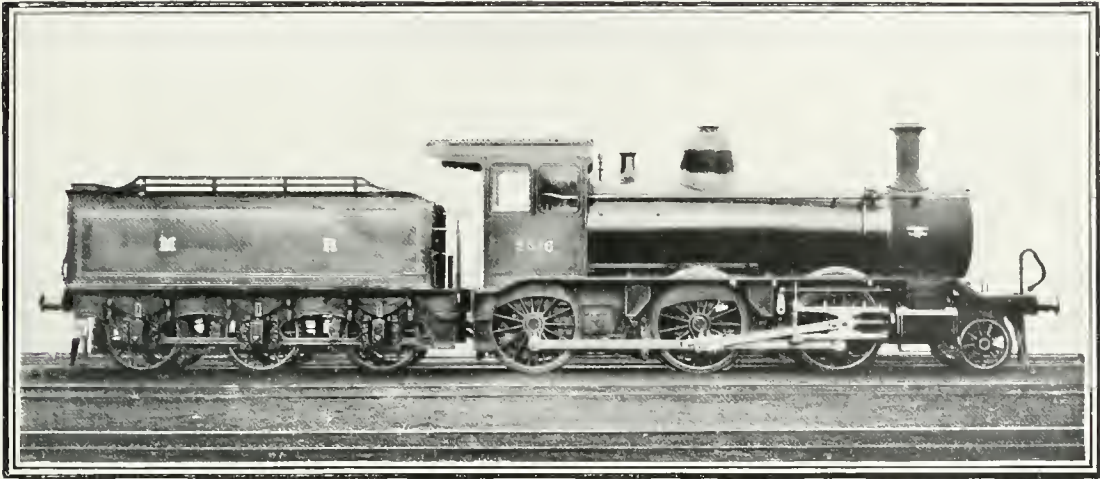
and was dictator of as many new projects as he cared to take under his wing. But the inevitable happened. The common sense of the public returned just as suddenly as it had disappeared. Visions of castles built out of railway plunging were shattered like glass. With the reawakening of discretion Hudson's power vanished. His fall was as complete and as dramatic as had been his rise. Some of his dealings when investigated dispassionately savoured of the fraudulent: shareholders accused him of double-dealing and working against their interests, which he ought to have protected. Blocks of shares were missing; and accusations of having bribed Members of Parliament heavily in order to force his dubious schemes to success were bandied on all sides.

Although Hudson was assailed when the

railway bubble was pricked, in reality he established the Midland Railway. He had embarked upon a wholesale policy of expansion and absorption, and the outcome was that the system of which he controlled the destinies secured a firm grip upon the Midland counties. Lines were run in all directions, so that within a short time

stretches of road were made, but when all was ready for signing the compact, the London and North Western, having heard of the move, stepped in, offered better terms, and forthwith secured the links, to the discomfiture of its rival.

Foiled in this attempt, the Midland determined more than ever to reach out



Photograph supplied by the Midland Railway Co.

AMERICAN LOCOMOTIVE BUILT IN THE UNITED STATES FOR THE MIDLAND RAILWAY

Although these engines were decried by the British critics they earned their cost in the course of the first year's service.

Derby became the hub of a great railway network, radiating in all directions, and tapping every important city, town, village and hamlet in the centre of England. On the west it reached out as far as Bristol. Where it could not construct, or a line was already in possession, either acquisition, leasing, or working agreements were drawn up. Odds and ends of every description were bought, and by being knit together were turned from useless into valuable properties.

Growing rapidly and prospering immensely, it was not surprising that some curious situations were provoked at times. For instance, the Midland cast covetous eyes upon Manchester. There were two lengths of line lying between Ambergate and "Cottonopolis" which would offer the very means of access to the desired city. Overtures for the acquisition of these two

to Manchester; it would build its own line. Naturally the project was fought tooth and nail by the London and North Western Railway. There was a short, merry fight in Parliament, but the grim pertinacity of the Midland won. It received permission to extend its line from Matlock to a station known as New Mills on the Manchester, Sheffield, and Lincolnshire—now known as the Great Central Railway—over whose metals it was thence able to run into Cottonopolis, and ultimately gave it a means of penetrating to Liverpool.

In forging this link the engineers had to traverse the bleak Peak district, making a tedious climb to a level of 985 feet to reach the summit. This is the country of the dales, and at places the work was heavy and expensive. The driving of the Dove Holes Tunnel, 8,580 feet, was the most

trying task. Although extending through limestone, straightforward work was hampered by subterranean streams, which occasioned many anxious moments. On this section, too, a heavy landslide provoked a serious situation. A lofty viaduct had been completed in brick, but the movement played such havoc with the work that it had to be demolished, and a temporary wooden structure run up.

The Midland, however, suffered most severely in regard to its traffic to and from the South. Rugby was its outpost on the London side, and here all the business was turned over to, or taken from, the London and North Western Railway. A very good idea of the extent of the volume of this business may be gathered from the fact that by the year 1862 the annual amount paid over to the rival in respect of this traffic was no less than £193,000. Seeing that the two were competing for business in a common territory, it is not surprising that the London and North Western strove to cripple its former competitor in this direction, and spared no effort to consummate its own ends.

The Midland Railway realised fully its peculiar position, and so decided to secure competition for its southern business. In 1862 it sought powers to build a new line from Leicester, through Kettering and Bedford, to Hitchin, where it could effect a junction with the Great Northern Railway. This offered a shorter haul over a "foreign" line as compared with Rugby, and the London and North Western, recognising that a profitable source of revenue was threatened, fought the project tenaciously, but the promoters had too strong a case, and so won the day hands down. Then a lively bid for Midland business ensued between the Great Northern and the London and North Western Railways, to the benefit of the third party, which now secured a far better service in regard to this class of business than ever had

been the case before. It played one line against the other very effectively, but the Great Northern held the stronger position, as the proportion of revenue which had to be paid out by the Midland in this instance was smaller than via Rugby, owing to the shorter haul. In fact the Midland gave the Great Northern Railway so much traffic that the latter line became choked with it. During the course of one year no fewer than 3,400 trains were held up between Hitchin and King's Cross, the London terminus of the Great Northern, and this despite the fact that the latter line spent over £60,000 in improvements in anticipation of the greater volume of business which it realised must come when the Midland reached Hitchin.

Under such circumstances it is not surprising that the Midland Company decided that it had better carry its own metals into London, and so reap the full benefits of the traffic. This proposal met with strenuous opposition from the lines already in possession, but here again the ease presented was far too overwhelming to enable the opposition to break it down. The Midland proposed, not to proceed southwards from Hitchin, as might have been supposed, but from Bedford through Luton, St. Albans, and Hendon to the metropolis, and this proposal met with approval.

The site for the London terminus was the most searching problem in this move. Coming in from the North the line had little scope. A unique opportunity was afforded to build a huge union terminal in the metropolis, similar to those abroad, for the housing of the three lines entering London from the North, but the inter-jealousy was too keen to permit the varied and antagonistic interests to recognise the wisdom of such a departure, for those were the days when the advantages of pooling were not appreciated; when railways preferred to fight one another instead of pulling together.

**Southern
Difficulties.**

**Advance to
London.**

Forec of eircumstaneec compelled the system to pitch upon a site between the termini of the lines in possession, and accordingly a huge slum area, known as Somers Town, in the purlieus of King's Cross, was swept out of existence to make way for the new station.

In approaching the metropolis the railway was balked by one obstacle. This was the Regent's Canal, which

**Building
St. Pancras.**

ran roughly at right angles to the proposed location. The

waterway could not be diverted, so the company was faced with the task either of burrowing beneath or spanning the obstacle. The former would have necessitated placing the terminal underground with a steep approach. Bridging demanded that the platform area should be elevated so as to maintain the gradient. The company decided that the latter was the more satisfactory way out of the difficulty, and it was induced to such a decision by an economic circumstance. The Midland Railway taps Burton-on-Trent, the world-famous brewing centre. The beer traffic to the metropolis was certain to attain huge proportions, and the company would be faced with the task of providing storage for this commodity in London. Why not utilise the basement area of the terminus as a beer store? The suggestion was found eminently practicable, and forthwith was adopted, the engineers being urged to make the utmost of the storing capacity below the platfrom area. The latter did so, adopting iron pillars in preference to brick arches for the support of the superstructure, because iron occupied less space. As it has been ingenuously declared, "the planning of the track level was governed entirely by the number of beer barrels which could be accommodated beneath it."

The station itself is one of the most attractive in the world, while its huge and graceful single arched span roof compels technical attention. The arch has a clear span of 243 feet at ground level, and rises

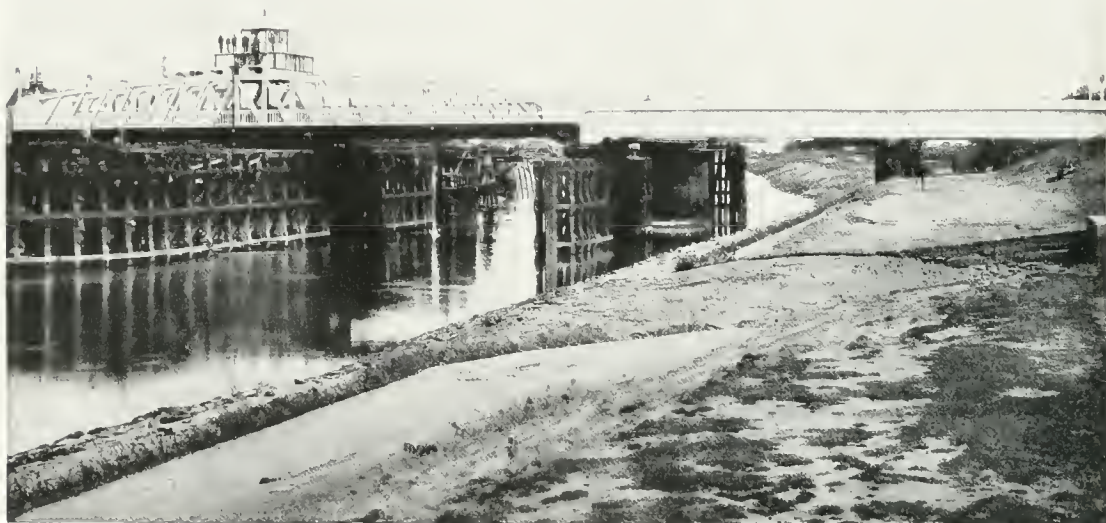
to a height of 100 feet above the metals, while the roof is 690 feet in length. In this manner an area of $4\frac{1}{2}$ acres are enclosed, sufficient for **St. Pancras.** housing 10 roads serving 7 platforms 800 feet in length. It was a daring proposal when outlined by Mr. W. H. Barlow, the consulting engineer to the company, inasmuch as it represented the largest work of its kind ever attempted in railway engineering up to that time, and never has been excelled, at least not in these islands. The south end of the station is flanked by a noble hotel, which is a good representation of Gothic architecture, and which in itself constitutes one of the most imposing and palatial buildings in the metropolis. By 1868 the first Midland express left St. Pancras for the North, thereby ushering in the Midland's direct touch with the metropolis.

But the system did not cease its aggressive tactics. Another valuable field awaited exploitation. The traffic of the Midland ramifies to all points of **To Scotland.** the compass, and the company found that this business was growing rapidly in one particular direction—northwards to Scotland. It had no means of coping therewith, as it did not possess any direct communication with the Border. Therefore it would make one. This, however, was easier said than done, because the Pennine Chain, running southwards from the Border like a backbone, stood directly in its way, and offered some of the roughest country which an engineer could wish to traverse—where construction was certain to be expensive and tedious. It succeeded in getting as far north as Settle, where the business had to be handed over to the London and North Western. Of course, inconveniences and disadvantages similar to those which had been experienced years before in regard to the London traffic were encountered. An independent line to Carlisle was imperative, so in 1866 a Bill was presented to Parlia-

ment seeking permission to bridge the 71 $\frac{1}{4}$ miles between Settle and the Border city. Once more strenuous opposition was offered by the line in possession, but once again it proved unavailing.

The work on this stretch proved to be among the most difficult experienced in

a serious obstruction, but the plotters overcame it by means of a viaduct, 1,328 feet in length by 165 feet above the foundations, to gain the opposite side of the depression. Then they had to tunnel for some 2,640 yards 500 feet below Blea Moor. After leaving Settle the plotters were forced,



THE SUTTON SWING BRIDGE.

Photograph supplied by the Midland Railway Co.

British railway engineering. Ragged crests demanding tunnelling alternated with deep rifts which had to be spanned, and progress was both slow and expensive. Construction came out at over £42,000 per mile, which, although high in comparison with the average of £10,000 to £12,000 per mile in other countries, was about the average prevailing in these islands, so was not so exorbitant as it appears at first sight.

The engineers followed the easiest course that was open to them. Leaving Settle they clung to the Ribbles Valley—crossing and re-crossing the winding stream so as to preserve the alignment and grade—to Ingleborough. Here the Batty Moss offered

from the configuration of the country, to give an upward pull for 16 $\frac{1}{4}$ miles to Dent station, which is the summit level—1,145 feet above sea-level—of the Midland Railway.

Beyond the summit comes another burrow, the Ruse Hill Tunnel, 1,205 feet long, while 5 miles beyond Hawes Junction, the alignment ran across Aisgill Moor, leading to the borders of Westmorland. Tunnel and viaduct in rapid succession were found unavoidable to reach Kirkby Stephen and Appleby, while some of the cuttings through the spurs attained impressive proportions. While the route extends through rugged country it offers



Photograph supplied by the Midland Railway Co.

THE MIDLAND SCOTCH EXPRESS—4.45 FROM CARLISLE—NEAR COTEHILL.



Photograph supplied by the Midland Railway Co.

THE FIRST VIADUCT SPANNING MILLER'S DALE, IN 1886.

magnificent vistas of the loftiest crests in England, so that the Midland Railway well deserves its colloquial title of "the most picturesque route to Scotland." By the time the railway builders had bonded Settle to Carlisle over £3,000,000 had been expended. The line was opened for goods traffic on August 1st, 1875, while nine months later it was available for passengers. From the railway's point of view the connection was worth every penny which had been laid out. Directly it secured an independent line to the Border city, where a junction was effected with the Scottish trunk roads, its business increased by leaps and bounds. From Bath, its western outpost, to the Scottish border the trains have a clear run of 320 miles, while a continuous line of 308 miles is offered from London to the North. In co-operation with the London and South Western Railway an entrance was also obtained to

Bournemouth, a joint line stretching from the pine tree resort to Bristol.

But the activity of the Midland has not been confined by any means to the penetration of new territory. The revolutions it has effected in regard to railway operation are equally noteworthy. It was the first to introduce the luxurious Pullman car into this country. Mr. (afterwards Sir) James Allport decided to make a bold bid for the London traffic, and thought that the railway coach which had proved so immensely popular in the United States would score an equal success here. Accordingly he ordered a drawing-room car from the American Pullman works. It was shipped over in sections and re-erected at Derby. A small charge over the first class fare was levied for the right to use this vehicle, this excess being handed over to the Pullman Company. Strange to say, British conservatism shunned the new

idea; the travelling public had become so wedded to the small compartment and its relative privacy that it would have nothing to do with the saloon carriage. However, the general manager, confident that his move was correct, stuck to his experiment. Slowly but surely the prejudice against new-fangled ideas was broken down, and within a few years the Pullman car became an indispensable unit of the Midland long-distance trains.

Gratified with this success, Mr. Allport decided upon another bold stroke. The introduction of the Pullman car had created virtually four fares, as compared with a scale of three upon other systems. To bring the railway which he controlled into line with the other roads he abolished the second class fare. The move was criticised severely, but it proved peculiarly successful, because the general appointments of the third class vehicle were raised to the prevailing standard of the second class coaches upon other lines. The result

was that the passengers favouring this type of accommodation preferred the Midland way to the North. The rival systems endeavoured to retain their business by reducing the second class fare to a small fraction in excess of the cheapest means of travel. It succeeded to a certain degree for a time, but the fact that the controller of the Midland destinies was more far-sighted than his contemporaries is evidenced to-day, because the second class coach is being rapidly eliminated from modern railway operation.

It must also be remembered that the Midland Railway first introduced the popular cheap excursion, and incidentally laid the foundations of the largest tourist travelling business in the world. An energetic citizen of Leicester, Mr. Thomas Cook, realised the fact that if only travel were made more attractive large numbers of people would take advantage of the opportunity, in the same degree that ladies will always flock to a bargain sale. So he



MILLER'S DALE VIADUCTS. 1905.

Photograph supplied by the Midland Railway Co.

The growth of traffic demanded a second viaduct, which was built beside the original structure.

approached the secretary of the Midland Counties Railway in 1841 with the idea of running a special train from Leicester to Loughborough at a cheap fare on the occasion of a temperance congress. Accordingly, on July 5th, 1841, was run the first excursion in railway history, the chance to make the 23 miles round trip for only one shilling proving so irresistible that 570 people took advantage of it.

The Midland Railway never has departed from its pushing and aggressive policy. Determined to participate in the remunerative Irish traffic, it established a new port at Heysham, created its own fleet of

steamers, and inaugurated a mail route between London and Belfast. Recently powerful evidences of its activity have been afforded by its acquisition of the London, Tilbury, and Southend Railway, which not only carries its operations into the south-east corner of England, but provides it with a strong hold upon the Thames maritime business. To-day the ramifications of the system extend to all corners of England, embracing 1,744 miles of line, and this vast network has been spun from the short length of 16 miles laid between the collieries of Swannington and Leicester city which was opened on July 17th, 1832.



Photograph supplied by the Midland Railway Co.

ST. PANCRAS JUNCTION SIGNAL BOX.



THE UNION PACIFIC "OVERLAND LIMITED" NEAR KEARNEY, EN ROUTE TO SAN FRANCISCO.
This crack train travels from Chicago to the Pacific port in 64½ hours.

The First Railway Across the United States—II

THE EVOLUTION OF THE UNION PACIFIC



IN 1870, the year following completion of the new highway, the Union Pacific owned 150 engines of all classes and 2,581 vehicles of all descriptions. Forty years later the rolling stock had grown to 660 locomotives and 16,550 vehicles. The movement of traffic over this highway was equally marked within the same period. In 1870 142,623 passengers were carried, while freight aggregated 71,779,106 ton-miles. Forty years later the number of passengers exceeded 4,383,000 annually, while the freight had grown to 4,148,750,600 ton-miles. In regard to the freight traffic there was a curious development within

this period. In the first year of operation the local freight ton-miles were two and a half times as heavy as the through ton-miles. Forty years later the position was reversed; the through freight ton-miles were practically double the local ton-miles.

Seeing that the transcontinental held a monopoly for several years, and rapidly became recognised as the overland route, its future appeared to be particularly rosy. But unfortunately the Union Pacific had incurred an impossible burden in supporting other subsidiary and unremunerative lines. The securities of these white elephants had been guaranteed, and the parent concern was compelled to fulfil its obligations to its own detriment.

In order to rid itself of these millstones it went into a receivership. It was an act of self-preservation, and could not be delayed beyond October 13th, 1893. But on January 1st, 1897, a new corporation arose. This was the Union Pacific Railway Company, formed for the express purpose to "purchase and operate railroads." The original undertaking, together with all its valuable properties and appurtenances, was put up for auction by order of the court. The sale—the biggest auction on record—was held in front of the goods station in Omaha on November 1st, 1897, and the hammer did not fall until a bid of £11,552,986 11s. 1d. was made by the new corporation.

Directly the new organisation secured control it started to rejuvenate the first transcontinental, so as to give it a new lease of life. A comprehensive scheme was drawn up and was commenced in 1899. Double tracking was carried out upon an extensive scale, iron bridges were pulled out and replaced by steel erections. Loops were eliminated in favour of straight tangents, and banks were eased on all sides. When Harriman assumed the presidency he carried out this reconstruction policy in the most vigorous manner, and poured out millions to bring the road to the forefront as the great overland highway across the continent. The new blood recognised the faults of the promoters, and incidentally appreciated the good work of the pioneers. Engineer Dey's original location near the Missouri River became appreciated after a lapse of nearly half a century, and a compliment to his knowledge and skill was paid by completing the Lane Cut-off, which is considered to be one of the four great achievements in modern railway building in the United States. It is a new stretch of line, 12 miles in length, but saves 9 miles out of 21 on the old line. Huge work was involved in its realisation, as wide valleys

**Harriman's
Vigorous
Policy.**

had to be spanned, and deep long cuts driven through humps. Some of the embankments are of imposing dimensions, while there is one cutting 85 feet deep, 437 feet in width, and 5,300 feet in length. To build this 12 miles of easy grade 4,000,000 cubic yards of earth had to be handled, and by the time it was completed £600,000 had been expended. Another big achievement was the relaying, double tracking and ballasting of 67 miles between Kansas City and Topeka, which ran away with a further £600,000. The shops at Omaha were reorganised and enlarged at a cost of £300,000. Automatic block signalling over 1,250 miles of the line was introduced, necessitating 22 interlocking plants working 497 levers, and absorbed £500,000. Ballasting the track with Sherman gravel, which gives a first-class, comfortable, and dustless road-bed, was commenced in 1892, and is being continued actively now. One of these days a gold rush will ensue, and the permanent way of the Union Pacific will be the Eldorado, inasmuch as recent analysis has shown this gravel to yield gold to the value of 8s. per ton.

Possibly the most spectacular achievement in the way of reconstruction is the "Lucin Cut-off," as it is called, which, leaving Ogden, makes a bee-line across the Great Salt Lake. The Central Pacific after reaching Lucin (Utah) swung boldly north-eastwards, so as to round the upper end of the salt sea. The Union Pacific in its westward march reached Ogden, on the eastern shore of the lake, and then the engineers swung northwards for the same purpose, the two arms meeting and being connected finally at a point known as Promontory. But rugged mountains force themselves to the water's edge on the northern shore, and the engineers, in compassing the great barrier of water, had a heavy up-and-down struggle, the rails having to be lifted to a height of 4,907 feet in order to negotiate Promontory Point.

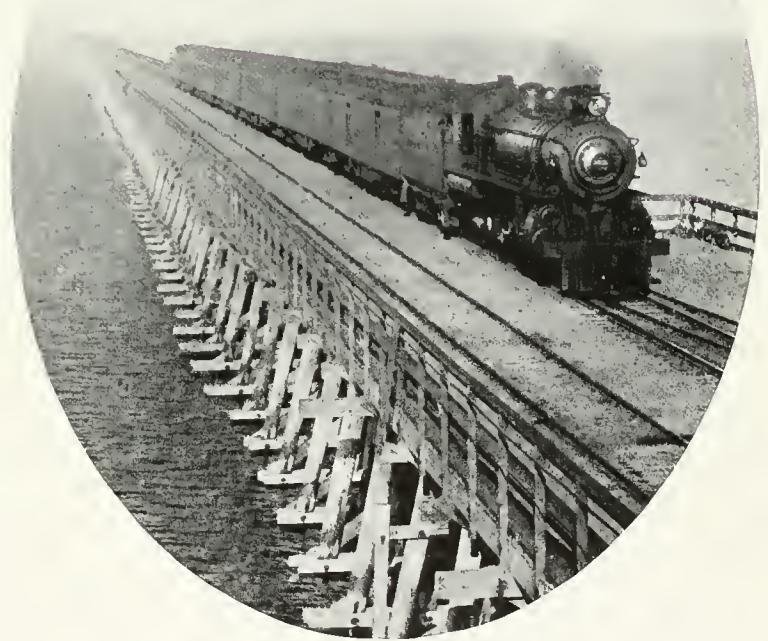
**The "Lucin
Cut-off."**

Then, going westwards, came a sharp drop of 684 feet in 16 miles, followed by a give-and-take road for 24 miles to encounter another heavy up-hill toil for 500 feet in 7 miles to reach Ombey. During the succeeding 29 miles the railway ran up and down the whole way, concluding with a big dip of 384 feet to enter Lucin, following a hard ascent.

It was an extremely arduous road over the 147½ miles between Ogden and Lucin, and although its adverse influence was not manifested very materially when only one train ran each way per day, yet when the transcontinental traffic grew the weakness of the link became more and more apparent, as the heavy trains hauled by powerful locomotives could not notch more than 12 miles an hour. The necessity for overhaul was only too apparent, and the engineers concentrated their energies upon the elimination, by hook or by crook, of this hard pull. The run round the south end of the lake was possible and easier, as it extended over desert for the most part; but there would be an increase

in mileage, and in this instance a reduction in grades and distance was the prime objective. At last the engineers conceived a daring scheme. The lake was 30 miles broad in the crow's flight between Ogden and Lucin, and the water was only 30 feet deep. Why not carry the metals on a timber trestle across the lake, and thus secure a level line? The engineers agreed that it would be costly, but when compared with alternative solutions of the difficulty

it was advantageous from all points of view. The plans were prepared, but the cost was too great for the finances of the road at the time, so it was shelved. Time after time it was withdrawn, but always returned, to its pigeon-hole, until Mr. Harriman



THE TIMBER TRESTLE FORMING THE "CUT-OFF" ACROSS GREAT SALT LAKE.

secured control of the railway. He grasped the extent to which the Promontory line was devouring profits, and he sanctioned the deviation immediately, with the further adjuration that no effort was to be spared to complete it as soon as possible.

In the original scheme it was intended to carry the railway metals on the timber trestles from shore to shore for 27½ miles. Then it was decided to make the first step of 4½ miles out into the water a solid



THE MOONLIGHT FLIGHT OF THE "OVERLAND

This engineering wonder of to-day, comprising 12 miles of timber trestle and 11 miles of embankment across the
By its completion the maximum grade was reduced to



LIMITED" ACROSS GREAT SALT LAKE.

breadth of the famous inland salt sea cost £1,000,000 and saved $43\frac{3}{4}$ miles in distance between Ogden and Lucin. 1 in 300, while $147\frac{1}{2}$ miles of the old line were abandoned

earthen embankment. But the engineer is averse to timber trestling if it can be avoided, and finally, after further reflection, it was decided to reduce the extent of open woodwork to 12 miles, the balance of 11 miles to be filled in with earth after the woodwork was established. The rail level was fixed at 17 feet above water level, at which point the permanent way was to be 16 feet in width.

Owing to the situation of the lake in the midst of a treeless country, the acquisition of the timber was a serious problem. Tracts of forest were secured in Louisiana, Texas, Oregon, and California for logs ranging from 100 to 150 feet in length.

The other arrangements included the bringing up of huge steam shovels to excavate the material for the earthwork ridge, as well as to level off protruding humps on the shore. A stern-wheel steamboat, the *Promontory*, was built, and floated on the lake to tow lighters, barges, and other craft from point to point with supplies and provisions for the constructional camps. Work was continued both day and night, the scene after dark being illumined by powerful electric lamps. Over 3,000 workmen found steady employment, and at times 400 earloads of ballast were sent seawards during the day. The aridity of the district rendered the supply of fresh water for the men and for domestic and machinery purposes somewhat perplexing. Every ounce had to be handled by train, and at times hauled between 80 and 130 miles. Every day 1,680 tons—336,000 gallons—of fresh water were brought up by train.

The huge pile-drivers drove the massive bunks into the bed of the lake with great rapidity, and on one occasion, when it was possible to keep them going at full pressure, the trestle advanced at the rate of 1,130 lineal feet per day.

The trestle is of substantial construction. At intervals of 15 feet five piles are driven in a row transversely to the track.

Just above water level a horizontal member, 8 inches thick, is bolted to them, with another bunk at the top, the latter being 18 feet long by 12 inches square, while diagonal members, 4 inches thick, are secured to hold the whole "bent," as it is called, firmly and rigidly, so that the piles cannot splay outwards under the superimposed weight. Each bent is connected to its fellow on either side by eleven heavy bunks laid parallel to the track. The road-bed comprises a coat of asphalt laid upon the stringers or longitudinal timbers, with a superimposed layer of rock ballast 12 inches in thickness supporting the sleepers and rails. By the time the two arms of the highway met in mid-lake 38,256 piles had been used. A forest two miles square had been transplanted in Great Salt Lake.

By means of this short cut across the inland salt sea the distance between Ogden and Lucin was reduced by $43\frac{3}{4}$ miles. But what is far more important to the railway manager is the elimination of the heavy grades and sharp curves incidental to the old line. For 36 miles it is dead level; in another 18 miles the rise is not more than 1 inch in 50 feet, while on the whole 103.8 miles the gradient nowhere exceeds 4 inches in 100 feet. The total cost of the deviation was about £1,000,000.

Some other heavy overhaul work has also been carried out upon the Union Pacific Railway. One of the first hindrances to speed and economical operation to be taken in hand was the 512 miles between Cheyenne and Ogden. In all 158 miles were rebuilt, and 188½ miles of line abandoned, the distance between the two points being reduced to 481½ miles.

The heaviest handicap on the old line was the climb over Sherman Hill, where the inclines ran up to 97.7 feet per mile in the 30 miles between Beaufort and Loraine. Formerly 15 extra locomotives had to be stationed at these points to assist passing

**How the
Trestle was
Built.**

**The
Promontory.**

**The Dale
Creek Bridge.**

trains over the hill. The engineers accordingly ran a new survey between Beaufort and Loraine in search of an easier route. They succeeded in their quest, and although they could not reduce the mileage—in fact, the revision is 0·3 of a mile longer—they found a means of pulling the maximum gradient down from 97·7 to 43·3 feet per mile. The surveyors elaborated a means

an embankment 120 feet high. In this last instance the realignment of the route brought about the abandonment of the Dale Creek steel trestle bridge, which, 650 feet in length by 130 feet in height, constituted one of the “sights” of the line. When the new route was opened this structure was demolished. The summit tunnel had to be driven through solid



THE WEBER BRIDGE AND TUNNEL, UTAH.

of avoiding the summit by cutting a tunnel for 1,800 feet through the crest, at an elevation 230 feet below the level where the old line crossed the obstruction. The relocation entailed the building of three huge embankments, one of which, across Lone Tree Creek, is 300 feet in length by 130 feet in height, in the building of which 350,000 cubic yards of earth and rock were used, while in order to maintain the grade across Dale Creek, 500,000 cubic yards of material were required to fashion

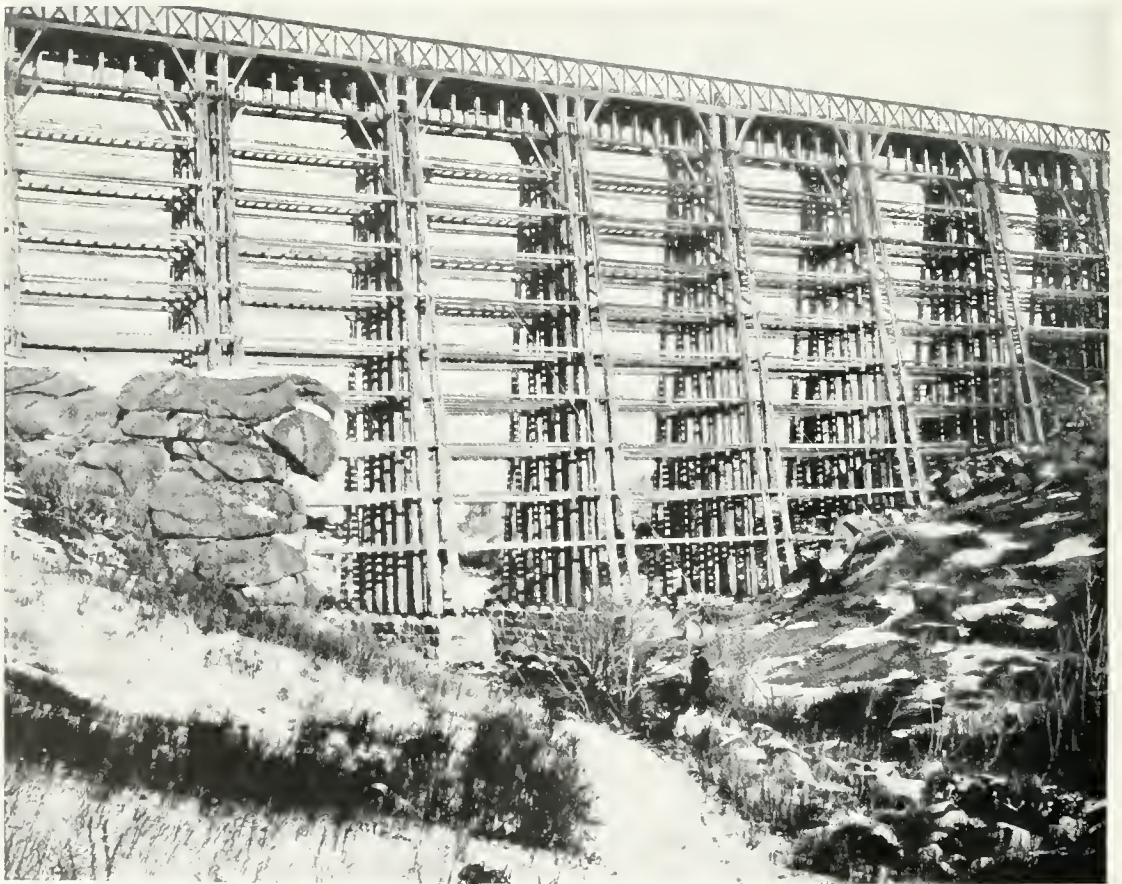
granite the whole of the way. The 30 miles of new line cost £3,000,000, and although this appears to be an enormous expenditure to improve such a short section, the money was well spent. The 15 “pusher” locomotives, which had had to be kept in readiness day and night to help the trains, were removed to more useful spheres, as freight trains and expresses are able to surmount the ridge unaided.

Another revision of great importance was between Howell and Hutton, where 3·11

miles were saved in a distance of 15 miles. The straightening out and flattening of the banks were equally severe in this section, as the maximum gradient was brought down from 52.8 feet to 43.3 feet per mile, while the curves were improved from 1,146 feet to 4,297 feet radius. In order to overcome the summit without exceeding the maximum gradient, the engineers had to drive a cutting 65 feet for $1\frac{1}{4}$ miles, while in order to get through another hump in a similar easy manner, they had to dig a huge trench 80 feet deep for 1,000 feet. In overhauling this 15 miles over 5,400,000 tons of excavated earth were handled.

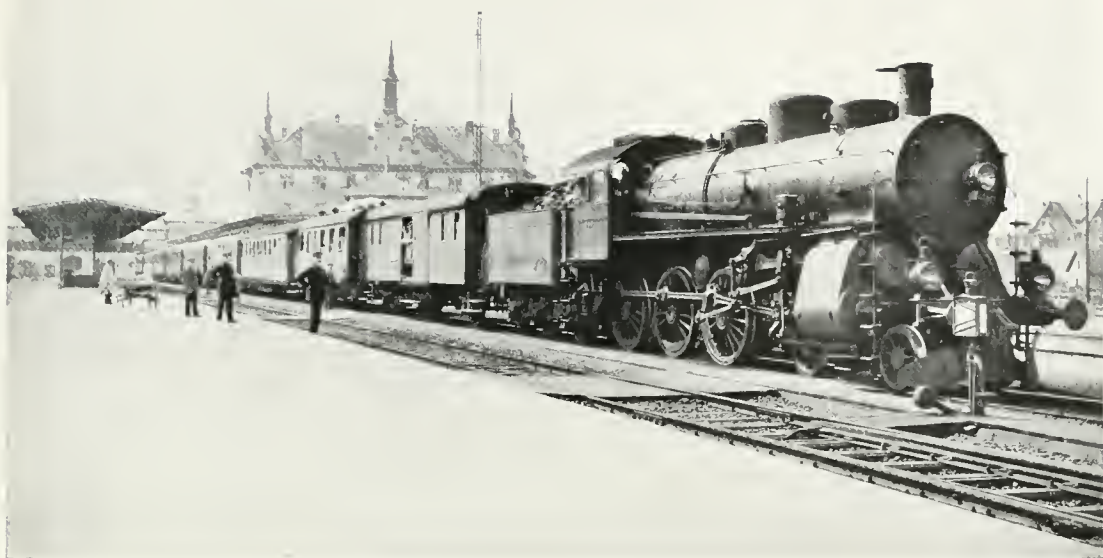
The money which has been poured out to bring the first American transcontinental up to date aggregates millions. Harriman never hesitated to sanction the expenditure

of a million pounds when he saw that he could make money by it. With him it was not a question of "How much will such-and-such an improvement cost?" but "How much will it save?" When his engineers proved that the interest on the outlay would leave a good margin from operation to go into the net revenue they were told simply "to go ahead and hustle," so that the benefit might be felt as soon as possible. The pace the financial and railway magnate set when in control has been maintained ever since, which explains the reason why the first railway across the United States yet is able to hold its own against its many powerful competitors as the shortest, quickest, and most direct link of communication between the Atlantic and Pacific coasts.



THE DALE CREEK TREESTLE.

This bridge, 650 feet long by 130 feet high, was demolished when the line was reconstructed.



Photograph supplied by the Swiss Federal Railways.

THE ST. GOTTHARD EXPRESS HAULED BY THE LATEST TYPE OF 4-6-0 STEAM LOCOMOTIVE.

Famous Expresses—IV

SOME CONTINENTAL AND INDIAN TRAINS DE LUXE



THE remarkable growth of traffic between London, Switzerland, and points beyond has been responsible for an increased demand for locomotive effort among the different countries through which this flow of traffic passes. This development has been particularly noticeable in Switzerland, where the heavy grades among the mountains exercise such an adverse effect. Notwithstanding this handicap it is possible to cover the 842 miles between the English capital and Milan by means of the crack expresses in 24-25 hours.

The Swiss Government has assiduously cultivated fast travelling over the lines under its control, inasmuch as it is threat-

ened by the French route to Italy which goes by way of the Cenis Tunnel. During the past few years more and more powerful locomotives have been designed. They are of the 4-6-0 type, and divided broadly into two classes. While one locomotive is capable of drawing the train unaided over the average or valley stretches of the system, double-heading has to be employed to lift it over the steep banks of the Gotthard Tunnel section, while the Simplon Tunnel is worked by electric haulage, as described in a previous chapter.

The most powerful Swiss express locomotives are four-cylinder compounds. The road engines have high-pressure cylinders measuring $16\frac{3}{4}$ inches in diameter, while the low-pressure cylinders are $24\frac{3}{4}$ inches

in diameter, the stroke being 26 inches. The driving wheels are 70 inches in diameter, and the weight distribution is 15.9 tons upon the front driving axle, and 16 tons upon each of the other two axles, giving a total adhesive weight of 47.9 tons. The boiler has a minimum diameter of 63 inches. The total heating surface is 2,195 square feet, and the grate area 30 square feet. Steam is used at a pressure of 210 pounds. In running order the engine weighs 73 tons. The six-wheeled tender has a capacity for 7 tons of coal, in addition to water, and loaded weighs 41.8 tons, bringing the total weight of the locomotive to 114.8 tons ready for the road. The maximum speed attainable is 80 miles per hour.

The engines engaged in pilot service have high-pressure cylinders $15\frac{1}{2}$ inches and low-pressure cylinders of 25 inches diameter, with a common stroke of 25 inches. **"Helper" Locomotives.** The driving wheels are $63\frac{1}{2}$ inches in diameter. The total heating surface is 2,540 square feet, while the grate area is 36 square feet. The total weight of the engine under service conditions is 79 tons, of which $49\frac{1}{2}$ tons are disposed over the driving axles. The six-wheeled tender has capacity for 5 tons of coal, in addition to water, and weighs, in running order, 39.2 tons, bringing the total weight of the locomotive to 118.2 tons, while its over-all length is $57\frac{1}{4}$ feet. Its rated maximum speed is 72 miles per hour.

The maximum travelling speeds of trains in Switzerland are controlled rigidly by law, and the steps taken to ensure these maxima not being exceeded are of an elaborate character. The supply of a tachometer in the cab of the engine is compulsory for the assistance and guidance of the driver. The speeds which are set down can only be exceeded by special arrangement, which, it may be mentioned, is not extended readily. The restrictions vary, but are specified under one of three broad headings. Passenger trains fitted with

continuous automatic brakes are allowed to attain a maximum speed of 72 miles per hour so long as the number of axles does not exceed 44. With from 45 to 52 axles the speed is reduced to 60, and from 53 to 60 axles is restricted to 52 miles per hour. Trains which are not fitted with a continuous brake have their maximum speeds reduced somewhat severely, those in passenger service up to 60 axles and goods trains up to 120 axles being permitted to run at 36 miles per hour.

Curves and gradients also affect the issue. While an automatically braked passenger train may attain a speed of 68 miles per hour on a bank ranging from 1 in 100 to 1 in 80, it must not exceed 40 miles an hour on gradients ranging from 1 in 36 to 1 in 33. The speed round curves is graduated in a similar manner. On curves ranging from 1,640 to 1,475 feet in radius 58 miles per hour are allowed, but on curves ranging from 656 to 577 feet in radius the speed is restricted to 40 miles per hour. Where a line has curves of less than 577 feet radius or banks heavier than 1 in 33 the authorities make special arrangements. As the tachometers are designed to give a continuous graphic record of the speeds attained throughout a journey, and as their working is automatic, tampering is impossible.

India is claiming an increasing number of visitors every year, and an innovation which will meet with the greatest appreciation has been introduced by the

Indian "Tourists' Hotel" Train.

Great Indian Peninsula Railway. This is the "Peninsula Express," or, to quote its colloquial title, the "Tourists' Hotel" train, which has been provided as a compensation for the indifferent hotel accommodation available in the smaller cities of Upper and Central India. In order to attract the travelling public to the wonders of our Indian Empire the management of the Great Indian Peninsula Railway realised



THE DEPARTURE OF THE NORD EXPRESS.

The French "flyers" of the Chemin de Fer du Nord, hauled by powerful "Baltics" (4-6-4), are among the fastest trains in Europe.

that some special effort was necessary. The carriages of this train de luxe are of the very latest vestibuled type, and it is, in fact, a "club on wheels," with every possible convenience to be found in a first-class European hotel. The broad gauge of this railway gave the carriage superintendent, Mr. A. M. Bell, M.I.M.E., excellent scope to secure spaciousness in

are built upon the corridor principle, with both longitudinal and transverse berths arranged in cabins for two or four occupants. In this manner absolute privacy is assured, while each cabin is fitted with electric light, fans, ample space for hand-baggage and other conveniences.

The personal baggage of the passengers is carried in the front vehicle, which is a



Photograph supplied by the Swiss Federal Railways.

4-6-0 DE GLEHN EXPRESS LOCOMOTIVE IN ROAD-SERVICE ON THE SWISS FEDERAL RAILWAYS.

the compartments and saloons, a factor of which he has taken the utmost advantage.

Visitors to India who travel over this system, and who take advantage of this travelling hotel, practically live on the train during the whole of their trip. As a rule it moves from point to point in accordance with a planned itinerary, the departure from one centre for another being timed in the evening about the dinner hour. This gives ample opportunity during the day for sight-seeing, and at the same time ensures travelling at about the most convenient and pleasant time.

Special attention has been devoted to the designing and equipment of the sleeping accommodation to ensure the utmost pleasure and comfort. The "sleepers"

combination car. Here it is stored in cloak rooms under the care of a conductor, and whenever necessary a particular bag or trunk can be discovered instantly. This combination car also contains compartments for the accommodation of the private servants of the travellers, a fully equipped bathroom, and a number of private dressing-rooms, the latter being finished with tiled floors and enamelled walls.

The "parlour" car offers a seductive smoking lounge, a dainty ladies' boudoir, and a general reception-room. There is a buffet, library, and also a pianola for whiling away the idle evening hours.

The "restaurant" car, capable of seating 40 persons, is of imposing dimensions. The separate tables are lighted by bracket

electroliers, while a number of powerful electrically driven punkahs ensure a cool, refreshing atmosphere. There is a commodious kitchen fitted with a large gas cooking range, grill, boilers, etc. A pressure filter of large capacity secures a constant

All windows are fitted with dust screens and venetian blinds. Last but not least there is a complete telephone installation fitted throughout the train. Smart attendants in uniform are deputed to attend to the passengers' comforts and wants in the



THE "PENINSULA" OR "TOURISTS' HOTEL" EXPRESS

This train inaugurates a new era in Indian railway travel and gives the maximum comfort and

illimitable supply of cool, filtered water. All stores, provisions, and ice are carried in a store van adjacent to the kitchen, which also offers accommodation for the train crew, attendants, and other servants.

Special attention has been devoted to efficient and adequate ventilation, while the roofs and sides are double, with a layer of heat-resisting or non-conducting packing between. All the fittings and upholstery have been carried out in a manner adapted to Indian requirements.

manner of stewards on board an ocean liner. Inclusive fares are charged, no extras being permitted, so that the visitor knows before he starts exactly what the journey is going to cost.

Among European railways the expresses of the Chemin de Fer du Nord compel attention, because they offer striking expressions of fast railway travelling. Many of the crack trains upon this system attain and exceed an average speed of $56\frac{1}{2}$ miles per hour. Pride of place, however, is held

by No. 197, in the Paris-Berlin service. This covers the 149 miles between Paris and Erquelines in the schedule time of 2 hours 31 minutes, giving an average speed of 59.2 miles per hour. Train No. 67, on the Paris-London route, also accomplishes some

275 tons. In the case of the Calais-Paris express, which is composed exclusively of Pullman cars of the Compagnie des Wagon-Lits, the train weight is 250 tons in summer. During the winter season the load is increased up to 400 tons, inasmuch



OF THE GREAT INDIAN PENINSULA RAILWAY.

luxury to tourists. The travellers live on the train, which moves from point to point during the night.

magnificent running. The 184.7 miles between Paris and Calais are timed to be run off in 3 hours 15 minutes, which represents an average speed of 56.83 miles per hour. These two trains are not only the fastest upon the Nord system, but also rank first in point of speed for their distance upon the Continent.

The average load hauled by the locomotives in the Paris-Berlin fast services, comprising first and second bogie cars, is 235 tons, increased upon occasions to

as this train constitutes the "Calais-Mediterranean Express."

These crack trains are hauled by the well-known Nord Pacific (4-6-2) engines, weighing, in running order, 86 tons, of which 49.17 tons are available for adhesion. The drivers have a diameter of 80.3 inches, while the total heating surface is 2,292.5 square feet. Huge powerful Baltics (4-6-4) locomotives have also been constructed for these services, a description of which is given in another chapter.



Photograph supplied by the Swiss Federal Railways

THE LOWER TERMINUS OF THE PILATUS RAILWAY.

The Steepest Mountain Rack Railway

THE WONDERFUL AND NOVEL RACK RAILWAY, 15,125 FEET IN LENGTH,
WHICH CLIMBS MOUNT PILATUS TO AN ALTITUDE OF 6,791 FEET



THE successful ascent of the Rigi by the rack railway laid down by Messrs. Riggensbach, Naef and Zschokke in 1871 prompted other clever railway engineers to essay even more audacious works of this character. Among these were Colonel Edward Loher and Mr. E. Guyer-Freuler, of Zurich. Their project, however, was more startling than any which had been suggested previously, because they proposed to scale Mount Pilatus.

When the idea became known it was received with incredulity. "Why, the Pilatus is one of the steepest mountains in the

country, affording scanty foothold for a chamois, let alone a heavy twin ribbon of steel," commented the critics. Such an opinion was justified, because this particular peak is among the most uninviting to the railway engineer in the whole of the land of the Cantons. The peak thrusts itself 5,344 feet into the air, like a huge granite tooth, and its flanks are scarred by deep, precipitous ravines and sheering cliffs.

It seemed to be a mad idea to plot and build a line over such terribly broken and difficult slopes, and as the conditions became realised, speculation as to how the engineer would reach the crest grew more and more keen. The grades would be terrific, and



Photograph supplied by the Swiss Federal Railways.

THE STIFFEST BANK ON THE PILATUS RAILWAY.

The rise is 48 in 100.

quite impossible to work even upon the Riggenschach system, while the rock-slides and snow movements would jeopardise the safety of the steel highway incessantly.

When the promoters of the enterprise communicated their proposals in detail, the scheme was considered to be more impossible than ever. The engineers did not intend to follow a tortuous route so as to provide grades within reasonable possibility of working, but intended to make as much of a bee line to the summit as possible. Towering precipices and yawning ravines were not to be avoided. The former were to be tunnelled, and the latter spanned, and in such a way as to defy the most playful antics of Nature.

Nor was this all. The two enterprising engineers who had outlined the scheme

recognised that neither the Riggenschach nor the Marsh rack systems would suit this railway, and so had evolved a principle of their own which differed from its prototypes completely. Instead of laying a central rail with the teeth provided on the upper edge in which vertical driving wheels on the locomotive were to engage, they designed a rack rail with its teeth on either side face, with which horizontal wheels fitted to the locomotive were to engage. It was virtually a modification of the Fell centre rail system, only with geared horizontal wheels meshing with a rack instead of smooth wheels gripping a smooth rail.

The authorities being convinced that every possible precaution to ensure safety had been incorporated, both in the character of the permanent way and the rolling stock, extended the necessary sanction, and constructional work commenced in 1887. The surveys provided for a track 15,125 feet—nearly 3 miles—in length, in which distance a difference of 5,344 feet in elevation was to be overcome. A gauge of 2 feet 7½ inches was adopted, as meeting the situation very completely. Owing to the severity of the grades an extremely

massive permanent way was inevitable, and accordingly it was decided to carry out the latter in solid masonry throughout.

The railway starts from Alpnach-Stad, on Lake Lucerne, at an elevation of 1,447 feet, and the line is virtually a continuous wall of solid granite with a top covering of granite slabs. The bridges are wrought in masonry throughout and upon exceedingly heavy lines. The metallic permanent way is of iron and steel well braced and bolted together, and anchored thoroughly to the rock beneath. The rack rail is laid centrally between the two running rails, but at a somewhat higher level. The lengths of rack rail are of wrought steel, with the vertical cogs milled out of solid steel bars.

In building this remarkable railway none of the conditions which ordinarily prevail in railway engineering obtained.

The line had to be pushed continuously and steadily from the lower station, so that like a stalk of wheat it grew higher and higher. As it proceeded the metals were laid for the purpose of bringing up stores, material, and men to the working face. Work had to be suspended for some six months in the open upon the approach of autumn, but tunnel boring continued the whole year round. At places the plotting was extremely bold, notably on one of the steepest banks, where a shelf was blasted and hewn out of the cliff side only a sufficient width to receive the permanent way. For maintenance purposes a footpath extends alongside the track in the most inaccessible places, while wooden gangways span the rifts and clefts for the convenience of the gangers.

The grade at places is terrific, and far in excess of the maximum found upon any other rack railway. The easiest rise is 1 in 5.2, and the mean gradient 1 in 2.8. But the steepest climb is no less than 48 in 100, which is nearly 1 in 2.

A New Rack System.

How it Was Built.

Owing to the extreme severity of the gradients a special type of steam locomotive had to be designed. The boiler could not be set in the normal position, owing to the extreme tilting, so it is disposed transversely in the combined locomotive and carriage. The seats, providing accommodation for 32 passengers, are disposed one above the other, while the underframe of the coach carries the locomotive's water, the tank being of 176 gallons capacity. The coach is carried on two axles on three points. The engine cylinders drive two pairs of horizontal toothed wheels through spur-wheel gearing mounted upon an intermediate axle, so that two driving wheels engage with each side of the rack rail. The leading gear wheel is used exclusively as a brake. The leading toothed wheels run freely when the carriage is ascending, and are locked by a special coupling when descending. The braking arrangements are of an elab-

orate character, comprising an air compression brake when running down hill, and a frictional brake on the crank shaft, in addition to friction and self-acting brakes on the leading pair of geared wheels which come automatically into action when the speed exceeds a certain predetermined limit. The carriage complete weighs about 12 tons, and the travelling speed is about 227 feet per minute, both ascending and descending, so that the journey in either direction occupies about 66 minutes.

Notwithstanding the unique and extreme difficulties of construction the railway was completed within the short space of 400 working days. It was completed in 1888, and opened for regular service in 1889. Although such a remarkably daring and difficult line to build, its cost was not excessive, being only about £76,000—approximately £25,000 per mile, including equipment.



Photograph supplied by the Swiss Federal Railway

THE UPPER STATION OF THE PILATUS RAILWAY.



Photograph supplied by the Westinghouse Company.

THE 1,000 HORSE-POWER 0-4-4-0 ELECTRIC LOCOMOTIVE OF THE NEW YORK, NEW HAVEN, AND HARTFORD RAILWAY.

This type is employed for heavy express passenger service, and with a maximum load can attain 50 miles per hour.

Electric Giants—II

SOME HUGE AMERICAN AND CANADIAN LOCOMOTIVES DRIVEN BY ELECTRICITY



WHILE remarkable progress has been effected in Europe in regard to the application of electricity for haulage purposes in connection with main line working, it is in the United States and Canada where the greatest strides have been made. Curious conditions such as do not prevail in these islands have brought about this supersession of steam.

Some of these developments, such as the adoption of electricity upon the New York Central and Hudson River Railway, and also the electrification of the Cascade Tunnel of the Great Northern Railway, have been described elsewhere. In both instances the utilisation of steam handicapped the lines concerned very appreciably.

Therewith the traffic capacity had attained its limit. Accordingly the roads either had to resort to electricity so as to increase the limit of the existing facilities, or were faced with the expensive alternative of providing additional tracks.

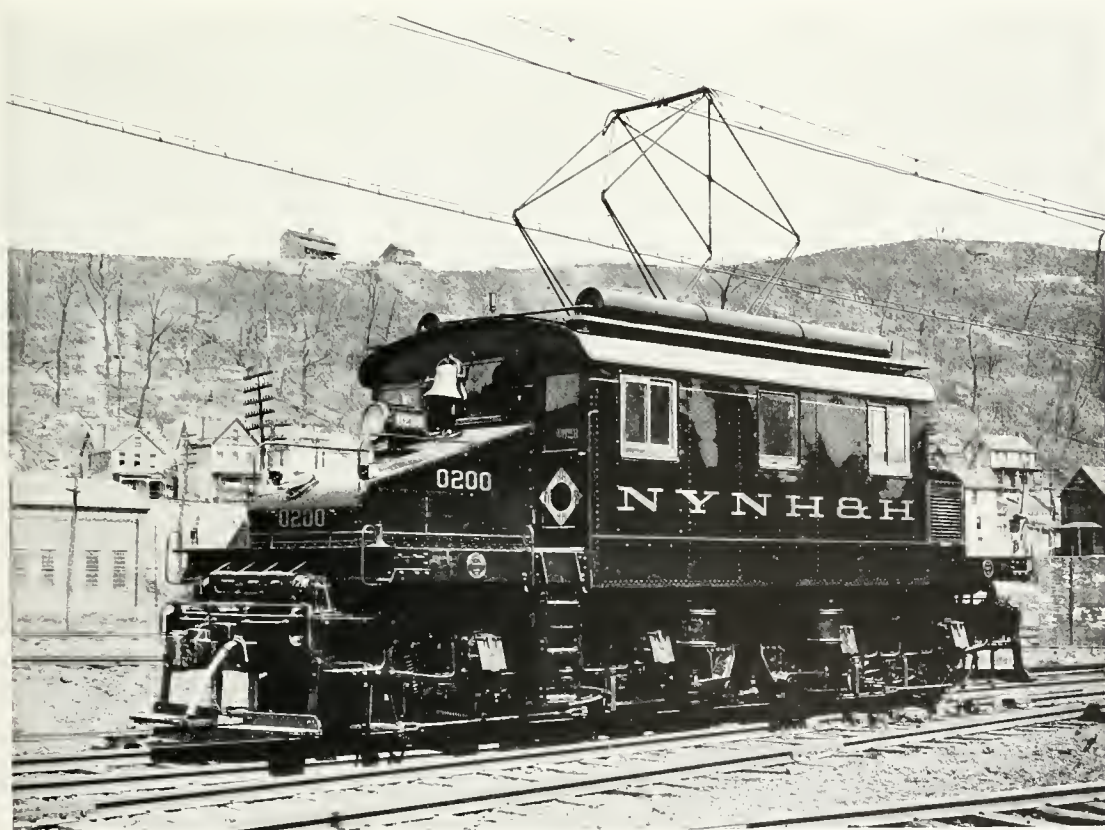
In both cases the latter was considered to be a premature solution of the problem. The Cascade Tunnel was merely an incident in trans-continental travel, and was called upon to cope with through traffic only. In the other instance a congested terminal and its requirements had to be studied. When the New York Central penetrated the Empire City of the Empire State, the former was relatively small and confined to the lower part of Manhattan Island. The directors of the railway failed to grasp the salient fact that when the city

commenced to grow it could expand in one direction only—northwards. Consequently they made no provision for the future by acquiring sufficient land for widenings and extensions. When the railway found itself hemmed in, and traffic so increased that the capacity of the line was reached under steam conditions, the engineers boldly recommended extensive electrification.

To-day no steam train runs in or out of the New York Central Station; electrical locomotives perform the whole of the haulage work, both for main line express passenger, goods, and local traffic. At a station outside the bottle-neck approach the incoming trains stop, the steam locomotives are uncoupled and the electric machines attached. Similarly upon the outward journey a pause is made at this point to exchange the electric for the steam

engines. Owing to the length and weights of the trains huge electric locomotives of immense power have been acquired. The largest are of the 4-8-4 type, with the four pairs of driving wheels coupled, and weighing ready for the road 115 tons. The drivers have a diameter of 44 inches, the weight per axle being $17\frac{3}{4}$ tons. The locomotives measure 43 feet over all by $13\frac{3}{4}$ feet in extreme height, and the rated output of the four direct current motors with which each is equipped is 2,200 horse-power, giving a guaranteed speed of 75 miles per hour.

For moderate speed heavy passenger and freight service a somewhat smaller electric locomotive is used, varying from 90 to 100 tons on the drivers. These are designed for the very heaviest railway operation. As in the case of the other



Photograph supplied by the Westinghouse Company

80-TON 750 HORSE-POWER ELECTRIC LOCOMOTIVE OF THE NEW YORK, NEW HAVEN, AND HARTFORD RAILWAY

This type is used for shunting operations.

electric engines supplied to this railway, they were built at the Schenectady works of the General Electric Company. They are of the 0-4-4-0 articulated type with four motors each of 300 horse-power rating. The drivers are 48 inches in diameter, and at a speed of 12 miles per hour a tractive effort of 35,000 pounds is developed, while the maximum safe speed with the locomotive running light is from 35 to 40 miles per hour. Over 35 locomotives of this type are in service to-day, and this number is to be increased as the electrified zone is extended.

In the application of electricity to steam railways the New York, New Haven, and Hartford Railway was among the pioneers, a section of 33.4 miles between New York City and Stamford, Conn., being converted thereto as a first instalment. As this system uses the Grand Central terminus of the New York Central and Hudson River Railway, and runs over their tracks for a distance of 12 miles, its locomotives are adapted to use the third rail direct system at 650 volts of the latter as well as the single-phase alternating overhead system at 11,000 volts of its own road.

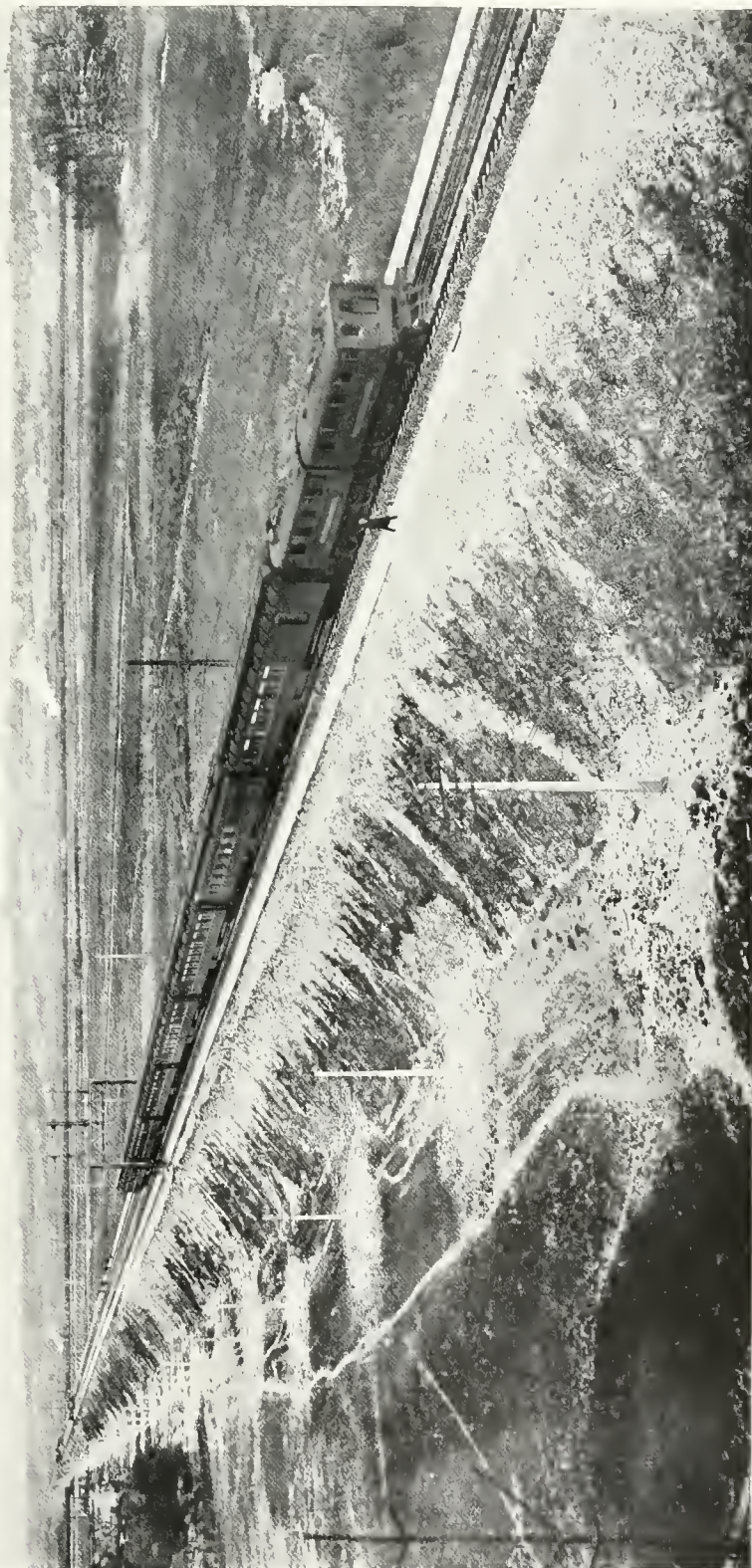
The bulk of the traffic on this railway is operated electrically. The heavy express passenger trains are handled by engines rated at 1,000 horse-power, capable of attaining speeds up to 50 miles per hour. The heavy goods trains up to 1,500 tons load are hauled by 1,250 horse-power locomotives at a maximum speed of 35 miles per hour, while 800-ton passenger trains are also moved therewith, the contract speed in this instance being 50 miles per hour. Electric locomotives are employed for shunting operations upon the electrified division, these engines weighing 80 tons and developing 750 horse-power. Electrification having proved such a complete success upon this railway, 250 additional miles of track, including 63 miles of goods-yard sidings, are in course of conversion.

When the Grand Trunk Railway of Canada laid a single-track steel tube beneath the St. Clair River to ensure a continuous rail journey between Chicago, Toronto, Montreal, and Portland, it was considered that a great problem had been solved completely. But within the course of a few years it was quite inadequate. Thereupon electrification was adopted, and it has met the situation very effectively. Electric locomotives, each consisting of two half-units, with each half-unit mounted on three pairs of driving axles, were designed. Each axle is driven through gearing by a 250 horse-power single-phase motor, so that the aggregate of the complete engine is 1,500 horse-power, capable of being increased up to 2,000 horse-power or even more if the exigencies demand. The engine weighs 135 tons, and it is designed to exert a draw-bar pull of 50,000 pounds at a speed of only 2 miles per hour. The locomotives are sufficiently powerful to start a train of 1,000 tons upon a bank of 1 in 50 if necessary, while the rated maximum speed is 35 miles per hour on the level and 12 miles per hour on the 1 in 50 grades of the approaches.

Six locomotives were acquired for service, and they now make 25 trips each way through the tube per day. As compared with the former steam locomotives the electric machines can cover the $2\frac{1}{4}$ miles in a third less time, and this, with a 1,000 ton train, represents the passage of 6,000 tons instead of 4,000 tons per hour through the tube. Some idea of the efficiency and sound design and construction of these locomotives may be gathered from the fact that during the first two years of service each locomotive covered 70,000 miles without a breakdown, while during one round twelvemonth's service there was but one delay to a train, and that only of eight minutes.

A long tunnel on the busy section of a big railway is a severe stumbling-block.

The St. Clair Tunnel.



Photograph supplied by the Hutton House Company

THE MAMMOTH 4,000 HORSE-POWER ELECTRIC LOCOMOTIVE HAULING A PENNSYLVANIA EXPRESS AT 60 MILES PER HOUR ACROSS THE MEADOWS JUST AFTER LEAVING NEW YORK CITY.

It not only strangles traffic, but safety in travelling is imperilled. The Boston and Maine Railroad discovered this fact in regard to the Hoosac Tunnel. This is the longest work of its character in the United States,

being forced to grope their way carefully through the smoke.

At last it was decided to ascertain what beneficial effects would arise from electrification, and this contract likewise was



Photograph supplied by the Westinghouse Company.

THE LARGEST AND MOST POWERFUL ELECTRIC LOCOMOTIVE IN THE WORLD.

It develops 4,000-horse-power and is employed for hauling trains through the New York tubes of the Pennsylvania Railroad Company.

being 25,081 feet from end to end. It pierces the Berkshire Hills lying between the Hoosac and the Deerfield Rivers. When the tunnel was laid out questions of drainage and adequate ventilation—the latter is always a troublesome factor in such undertakings—demanded close attention. The former requirement necessitated the provision of a gradient of 26.4 feet per mile from each portal to a short level stretch near the centre whereby all water is carried off. The ventilation problem was not solved so easily, although a ventilating shaft extends vertically from the centre through the hills above for a distance of 1,028 feet into the open air. Increasing traffic and the volume of steam discharged into the tunnel from locomotives struggling with heavily laden trains brought matters to a crisis. The service was increased until not another train could be put through the bore, while delays became frequent and serious owing to the drivers

carried out by the Westinghouse Company. Nearly 8 miles of track, including the $4\frac{3}{4}$ miles of tunnel, were converted. At each end of the electrified zone yards are provided for the shunting and accommodation of the electric locomotives. Single-phase alternating current at 11,000 volts was installed, and the service was opened on May 27th, 1911, since which date all traffic has been moved electrically through the Hoosac Tunnel. The locomotives of the 2-4-4-2 articulated type are fitted with four 300-volt 25-cycle Westinghouse railway motors. The drivers have a diameter of 63 inches, and in running order the machine weighs 130 tons. The mechanical equipment was built at the Philadelphia shops of the Baldwin Company, the well-known builders of steam locomotives, this firm, realising the future of the electric rival, having co-operated with the Westinghouse Company in this particular development.

These Boston and Maine electric engines are designed primarily for freight service, although they are utilised for passenger train work also. From 60 to 70 trains of all descriptions are carried through the Hoosac Tunnel in this way every day. Unlike the practice adopted in connection with the Cascade, St. Clair, and other electrified tunnels, the steam locomotives are not detached and coupled up at the respective ends of the tunnels. Upon the

opposite yard is reached, and the electric machine has been uncoupled. Goods trains up to 1,600 tons including the steam locomotive are hauled through in from 15 to 20 minutes, while the passenger trains, ranging from 400 to 500 tons in weight together with the steam locomotive, are able to negotiate the tunnel in 7 to 8 minutes. In this instance not only has electrification enabled heavier loads to be hauled and acceleration achieved, but it



Photograph supplied by the Grand Trunk Railway.

THE "INTERNATIONAL LIMITED" EMERGING FROM THE ST. CLAIR TUNNEL.

By means of 1,500 horse-power electric locomotives a train weighing 1,000 tons can be hauled through the tube.

arrival of a train at either of the electric junctions, the electric locomotive is attached to the front of the steam locomotive, and the latter passes through the bore with steam shut off, resuming steaming when the

has also enabled the railway engineers to cope with the ventilation difficulty very effectively.

But the heaviest electric locomotives in daily operation at present in any part of

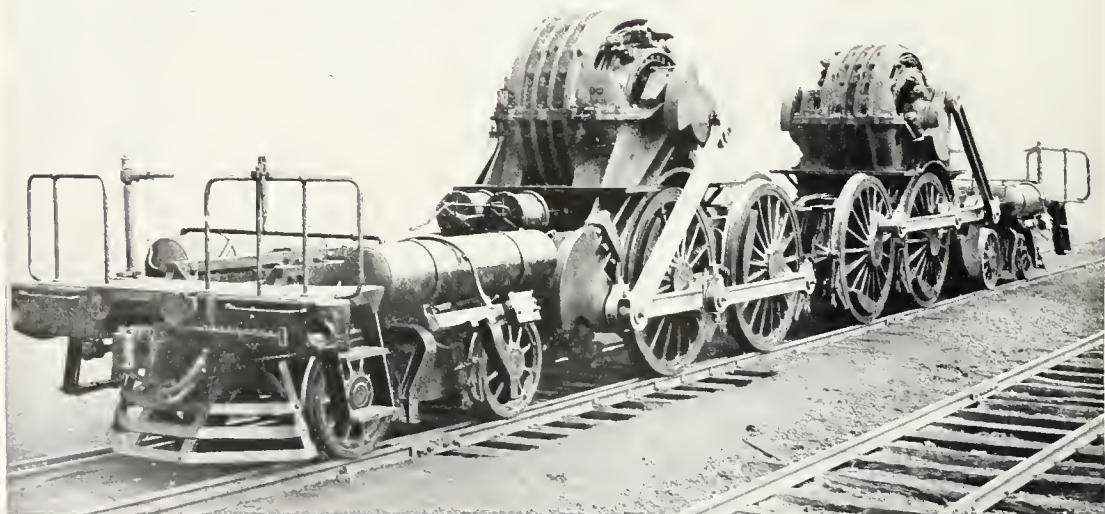
the world are the Westinghouse mammoths employed by the Pennsylvania Railway to haul all trains under the Hudson and East Rivers between the New York City terminus and the Brooklyn and New Jersey shores. When this company decided to establish itself in the heart of the city it realised the indispensability of electric working through the connecting tubes. The prevailing gradients and the heavy long trains demanded enormous power, and the Westinghouse Company thereupon was urged to provide a machine capable of fulfilling any possible emergency that might arise.

The outcome of prolonged experiments and investigations was the huge articulated 4-4-4-4 machines, 65 feet in length, and weighing 157 tons complete, capable of developing a maximum of 4,000 horse-power. These engines have drivers 72 inches in diameter with 50,000 pounds imposed on each axle, giving an aggregate adhesive weight of 200,000 pounds or 100 (U.S.) tons. The rigid wheel base of each half of the locomotive measures 7 feet 2 inches, while the total wheel base of each half is 23 feet

1 inch, and for the whole engine 55 feet 11 inches. The weight of each motor, including cranks, is 43,000 pounds. The contract called for a tractive effort of 60,000 pounds, and a normal speed, with full train load, of 60 miles per hour. In addition, owing to the severe grades in the tunnels, the locomotive had to be capable of starting and accelerating a train load on a bank of 1 in 50.

Under test the locomotive developed a maximum draw-bar pull of 79,200 pounds. These trains are called upon to perform very heavy duty, the average train entering and leaving New York City representing a dead weight of from 360 to 550 tons. The trial runs with this locomotive proving successful under peculiarly exacting conditions, an initial order for 24 such engines was placed with the designers, the mechanical equipment being built by the railway company itself at Juniata.

Although at the moment this 4,000 horse-power machine represents the heaviest and most powerful electric locomotive in the world, finality in this direction has by no means been reached.



Photograph supplied by the Westinghouse Company

THE MOTORS, EACH DEVELOPING 2,000 HORSE-POWER, OF THE LARGEST AND MOST POWERFUL ELECTRIC LOCOMOTIVE IN THE WORLD.



THE "M. J. BOND," ONE OF THE EARLIEST GEARED LOCOMOTIVES BUILT BY MR. EPHRAIM SHAY FOR LOGGING IN MICHIGAN

The Shay Geared Locomotive

THE DEVELOPMENT OF THE ENGINE KNOWN AS "THE HILL CLIMBER"



IN 1873 an enterprising American lumber magnate, Mr. Ephraim Shay, owned and operated an extensive saw-mill at Haring, in the centre of the Michigan lumber country. In common with his contemporaries Mr. Shay was puzzled how to keep his mill adequately supplied with logs. Hungry saws are like horses in a stable—financial loss results when they are idle or are not working steadily at their full capacity.

The greatest difficulty was the transportation of the logs from the forests to the mill. Lumbering being essentially a winter calling, it is obvious that advantage

must be taken of every minute of time. But the impassibility of the roads owing to snow and ice constituted a serious obstacle. Mr. Shay followed the conventional methods of logging by means of wheels and horses and encountered the general run of aggravating delays and difficulties, while the lumber was proving somewhat costly to bring down.

Under these circumstances he was forced to reflect whether a simpler, more expeditious, and cheaper system of haulage could not be introduced. The railway and the steam locomotive offered an obvious alternative, but he recognised that the conditions were adverse to its utilisation.

Circumstances demanded a permanent way of the cheapest possible construction, comprising virtually the laying of the pair of rails upon the ground surface, ignoring banks and curves. There was another



"THE HILL CLIMBER" ASCENDING A RISE OF 1 IN 20 ON THE MOUNT ARISAN LOGGING RAILWAY IN FORMOSA.

factor which had to be borne in mind. The rails would have to be moved time after time to tap the points where the lumber-jacks were at work.

Thereupon the ingenious saw-mill proprietor resolved to work out his own solution of the issue. He thought of a geared locomotive, where the power developed by the engines might be transmitted through shafting and gear wheels to the roads. The more he reflected the more convinced he became of its practicability.

He set to work to build a locomotive according to the ideas he had evolved. The materials and facilities at his command in the backwoods were severely limited, but this fact did not deter him. He

contrived some rails from maple wood, and laid them on rough sleepers fashioned from waste parts of the logs. He used the standard gauge because he bought some flat deck cars for his experiments, and they were built to this gauge. His locomotive was extremely crude. It comprised a vertical boiler which he placed upon a double truck flat deck car. At one end of the vehicle he placed his water-tank, while at the opposite extremity he rigged up a bunker for carrying wood fuel. The engine, with its cylinders set vertically, was placed upon one side of the boiler, while the piston rods, extending downwards, were connected to a flexible shaft extending longitudinally alongside the truck wheels, and gearing with the latter through bevel and pinion wheels.

Such was the first Shay geared locomotive. Its creator became the butt of ridicule among the camps for his pains. The locomotive certainly was a quaint-looking and primitive machine, giving every impression of having been made from odds and ends rescued from the scrap-heap. But it had cost its builder several hundred pounds, considerable thought, and many hours of tedious labour and disappointment. That it should be received with mirth galled him to the quick, and he accordingly resolved that, come what might, he would make it work successfully.

So it did, and to such advantage that those who had hailed its appearance with laughter began to regard the experiment with serious interest. Directly the locomotive got out upon the road all sorts of troubles asserted themselves, but as they developed its designer attacked and remedied them. The result was that at last he got it to work pretty smoothly, and evinced the greatest pride in the fruits of his labour, because he was able to haul his logs quicker, more continuously, and cheaper by this means than were his rivals with their horses.

As this was the object for which he had

striven he became completely satisfied with what he had accomplished. He proved that his locomotive could run and keep the track where an ordinary engine would fail completely. So he built additional improved engines, and in a short space of time Ephraim Shay's gear-driven locomotive became the talk of the American and Canadian lumber camps. Those who formerly had laughed at his efforts now wanted to avail themselves of similar facilities. In a short while Ephraim Shay became inundated with orders for similar machines.

Luckily he was a very shrewd man of business. The gibes of his competitors did not dissuade him from protecting the salient points of his ideas by means of the Patent Acts. Then inquiries began to roll in from other sources. Contractors who appreciated the advantages of mechanical haulage, but who were faced with similar conditions concerning primitiveness of track, banks and curves, having heard of the achievements of the Shay geared engine, wanted them for their works.

The designer not being able to meet these demands by his own efforts, transferred his patents to two concerns, the Carnes Agerter Company and the Lima Locomotive and Machine Company, since amalgamated and now known as the Lima Locomotive Corporation, of Lima, Ohio. The invention, now placed in the hands of experienced and expert engineers, was developed very rapidly along approved locomotive lines.

Colloquially it has become known as "The Hill Climber," and the nickname is appropriate. Its range of workability is wide both as regards gradients and curvature. It will climb banks ranging from 1 in 33 to 1 in 7, and will negotiate curves of 50 to 100 feet radius, conditions which it is safe to assert could not be fulfilled by many other types of locomotives with ease.

Although originally designed for service in lumber camps and upon contractors' works, it has passed to other more useful spheres. Being built in all sizes from 10 to 160 tons weight, it is equally applicable



SHAY GEARED LOCOMOTIVE ROUNDING HORSE-SHOE CURVE OF 164 FEET RADIUS AND RISING 1 IN 20 UPON THE MOUNT ARISAN RAILWAY, FORMOSA.

to trunk line working where stiff banks and sharp curves abound. True, its speed capacity is limited, but that is a secondary consideration so long as it moves the loads imposed to and from the points required.

Its salient peculiarity is the enormous power developed at slow speed, and its extreme flexibility in negotiating the sharpest curves. On the Mount Arisan

Railway in Formosa the banks run up to a maximum of 1 in 20, while the sharpest curves are only of 164 feet radius. Another interesting application is that upon the Mount Tamalpais Railway in California, where the heavy grades and sharp bends

are placed on one side of the centre line for balancing purposes, strongly supported on the frame, and immediately under the observation of the driver. Although two cylinders are sometimes used, three forms the usual practice, so as to bring the setting



THE LARGEST AND MOST POWERFUL
In running order it weighs 160 tons, develops a tractive effort of

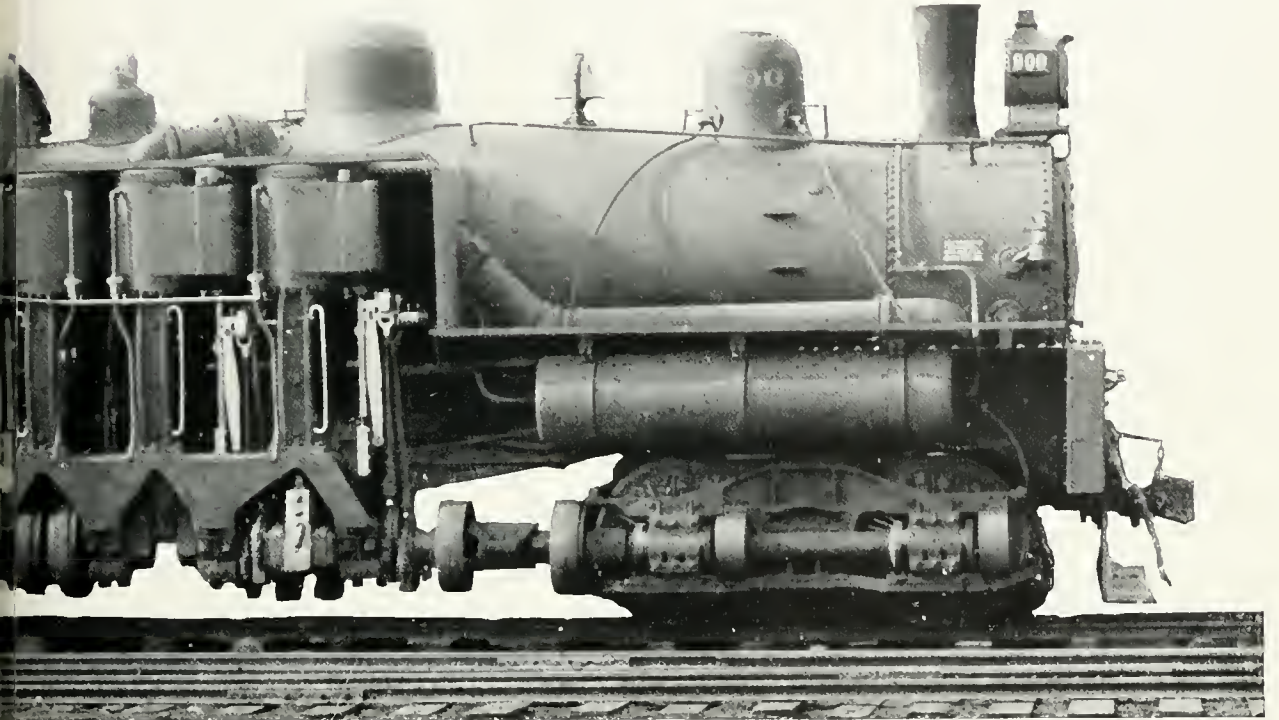
of this sight-seeing line are overcome by means of the geared locomotive.

The modern expression of the Shay geared locomotive differs very radically from its original prototype although the fundamental characteristics are retained. The vertical boiler was discarded in favour of one of the conventional locomotive type, thereby bringing it into line with general practice. The locomotive is built on centre bearing trucks, including the tender, which carries both fuel and water. The frame is of the plain girder instead of the special locomotive type, because it has to provide a foundation of support and strength. The inverted engines, either two- or three-cylinder according to the size of the machine,

of the cranks to 120 degrees. The vertical engines drive on a crank-shaft, which in turn is connected with the main line shaft, which is built up in sections and rendered flexible by means of universal joints and extension couplings. This shaft drives pinions which mesh with bevel wheels attached to the outer face of the truck wheels. Each wheel, both of the engine and tender, is geared, so that every wheel, irrespective of number, is converted into a driver. The gear ratio is about 19 to 42. Although three cylinders are employed, each is driven by high-pressure steam, the pressure of the latter being 200 pounds per square inch. When viewed from the driving side the locomotive certainly presents a

quaint and lop-sided appearance, but in its present form the locomotive represents the outcome of some 30 years' experience, so that the unworkmanlike design is more apparent than real. The driver has absolute control when ascending and descending the

working was quite out of the question. The issue was closely investigated and after examining the Mount Tamalpais Railway and its Shay locomotives, which have to run over similar grades, and where the curves range between 70 and 80 feet radius, and



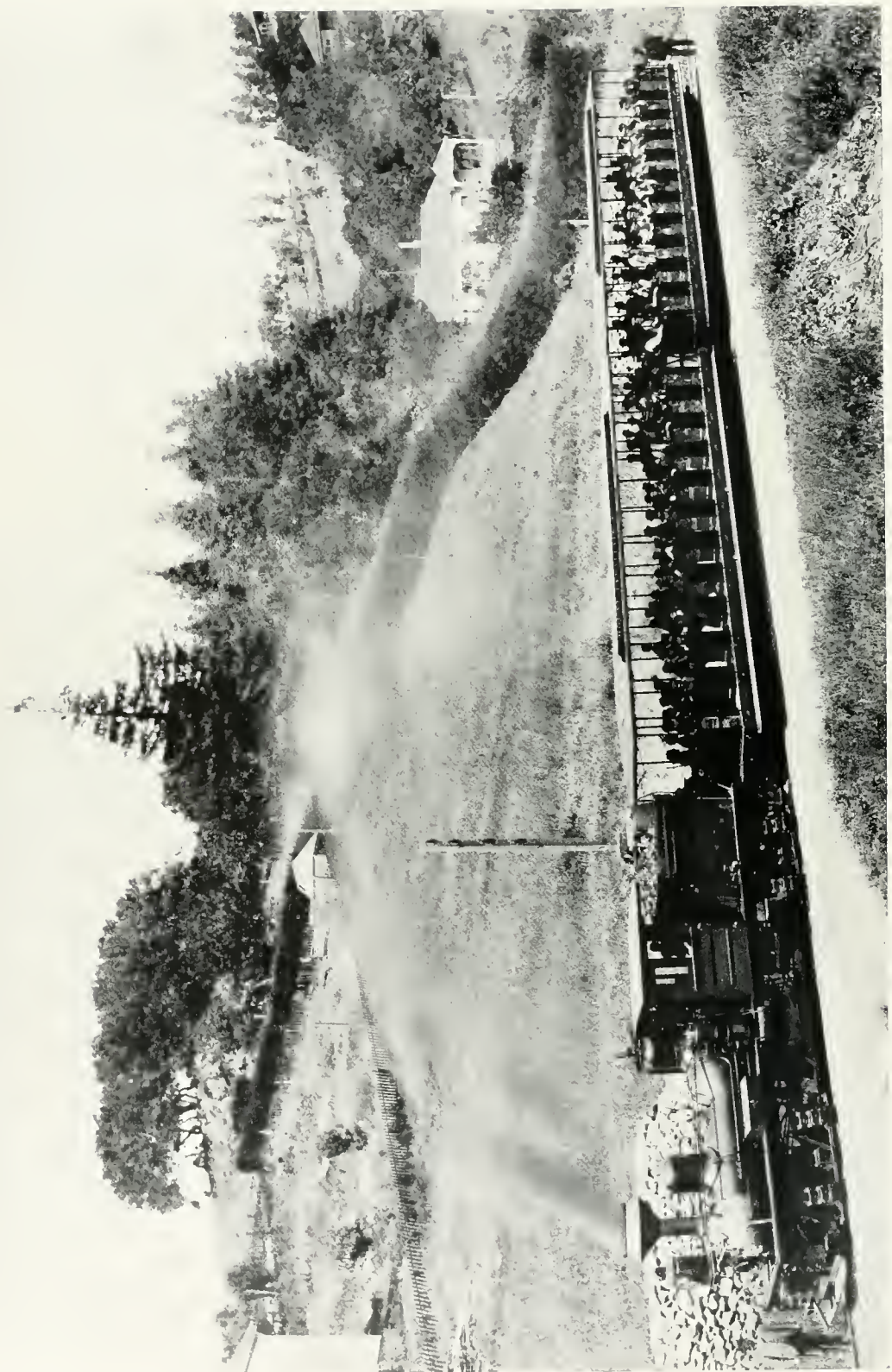
SHAY GEARED LOCOMOTIVE IN SERVICE.

74,400 pounds, and hauls a load of 200 tons up a bank of 1 in 14.28.

steepest grades. The machine is fitted with all the latest and usual locomotive fittings, and can, if desired, be adapted to the consumption of oil fuel.

When the Wolgan Valley Railway was carried some 30½ miles inland from Newnes Junction, on the New South Wales Government system, in order to tap the shale oil fields, the fact that some 1,760 feet difference in altitude had to be overcome in this distance offered a somewhat perplexing problem to the surveyors. The location gave banks of 1 in 22, and curves of 330 feet radius, which could not be eased owing to the configuration of the country. The operation of such a railway also occasioned considerable anxiety, as ordinary adhesion

also the Canadian Pacific Railway, where the Shay geared locomotives have to overcome curves of 230 feet radius, this system was adopted. In one particular case where Shay locomotives are at work it was found that whereas the maximum load capable of being hauled by the geared engine was 5,781 tons on the level, it could pull 1,556 tons up a bank of 1 in 100, 852 tons up 1 in 50, 484 tons up 1 in 25, and 235 tons up 1 in 16.66. The latter grade is quite impossible to ordinary adhesion working. The only alternative to the Shay geared locomotive was the rack system or the Fell centre rail such as worked the mail traffic over Mont Cenis during the boring of the tunnel, as described in a previous



THE SHAY GEARED LOCOMOTIVE AT WORK UPON THE MOUNT TAMALPAIS RAILWAY IN CALIFORNIA.

chapter. Seeing that the conditions fulfilled in this instance were closely allied to those which had to be faced in Australia, two 70- and one 90-ton Shay geared locomotives were acquired for the Wolgan Valley line, this decision being influenced by its flexibility in conjunction and the enormous adhesion.

In the country of its origin the Shay geared locomotive has been adopted extensively and many striking

**The Latest
Shay Geared
Locomotive.**

machines of this type have been built. The latest and most remarkable is that

designed for the Kansas City Southern Railway in connection with the operation of the new terminals of this system which have been completed on the north side of Kansas City, Missouri. This is the largest and most powerful geared locomotive in operation in the world to-day. It is of standard gauge with three cylinders, each of 18 inches diameter by a stroke of 20 inches, and 48-inch drivers. The boiler diameter varies from $67\frac{3}{8}$ to $79\frac{1}{4}$ inches, and steam is used at a pressure of 200 pounds. There are 347 two-inch boiler tubes 16 feet $4\frac{3}{4}$ inches in length between tube sheets with an aggregate heating surface of 2,910 square feet. The fire-box measures 120 by $68\frac{1}{2}$ inches, and has a heating surface of 185 square feet, so that the total heating surface is 3,095 square feet. The grate area is 57.1 square feet. The rigid wheel base is of 6 feet, and the total wheel base 52 feet 11 inches, while the over-all width is 11 feet 4 inches by 15 feet in height. The tender carries 5,000 gallons of water and 2,200 gallons of oil. In running order the locomotive weighs 160 tons.

The duty which this engine has to fulfil is of a very exacting character, and demonstrates very conclusively the enormous power developed by this geared system. Owing to every wheel being a driver and available for adhesion the locomotive is able to develop a tractive effort of 74,400 pounds. It was designed to haul a train load of 200 tons up a grade of 1 in 14.28 on which there are some sharp curves, and upon reaching the top of the bank to negotiate curves of 95.5 feet radius in order to move the cars to and from the various warehouses.

Despite the fact that this huge geared locomotive was built 30 years after the inventor, Mr. Ephraim Shay, contrived his first crude engine to facilitate his logging operations, strict adherence has been

**Triumph of
the Shay
Principle.**

made to the original Shay idea—the vertical cylinders are placed on the side, and are geared with each wheel by a flexible shaft, so that each wheel becomes a driver, and all the weight of the locomotive and tender is disposed over the driving wheels. Since Mr. Shay evolved his unique solution for overcoming an exasperating difficulty in the backwoods of Michigan several different types of geared locomotives have appeared, but it is interesting to observe that the Shay has more than held its own, over 2,000 locomotives of this type being in daily use throughout the world. Although the Mallet articulated, Fairlie, Garrett and other duplex forms have appeared since, the Shay geared locomotive still is preferred for service under conditions closely analogous to those for which it was first designed.



THE NEW YORK CENTRAL "TWENTIETH CENTURY LIMITED" MAKING 60 MILES AN HOUR ON ITS WAY FROM NEW YORK CITY TO CHICAGO.

Two Famous American Long Distance Flyers

THE "TWENTIETH CENTURY LIMITED" AND THE "BROADWAY LIMITED"



THE American is fastidious in his railway travel. He not only demands comfort, but speed as well. The competition to this end is very keen, especially for the busy traffic between New York and Chicago. Two lines, the New York Central and the Pennsylvania, are particularly aggressive in their efforts to capture this business. Both railways have spared no effort to perfect their permanent ways, and each strives to eclipse the other in point of equipment. The first-named offers the "Twentieth Century Limited," while the second seeks patronage with its "Broadway Limited," and both are magnificent expressions of comfort and luxury.

The "Twentieth Century Limited"

favours the valley of the Hudson to Albany, and thence through Buffalo and Cleveland to Chicago. The Pennsylvania takes a southern route to Philadelphia, and then bears through Pittsburg and Fort Wayne to the "Windy City." This is the shorter route, being 909 miles, as compared with 950 miles by the northern run. Although both trains have identical schedule timings — 20 hours — the "Twentieth Century Limited" puts up the higher average speed, viz. 47.5 miles per hour, the "Broadway Limited" maintaining an average of 45.45 miles per hour from start to stop.

Taking the New York Central first, its expresses for years have compelled attention. The Empire State Express probably is the most generally known, and this runs daily (Sundays excepted) between New

York and Buffalo, a distance of 438.73 miles, going west the schedule timing is 8 hours 59 minutes, an average speed of approximately $48\frac{1}{2}$ miles per hour, while coming east 9 hours and 10 minutes are allowed, an average of 48.2 miles per hour. During July and August of 1912 this train was late on three occasions westbound, the total delay being 29 minutes, while east-bound it was late nine times with an aggregate loss of 35 minutes.

The regular equipment of this train is seven vehicles—an extra coach is attached during the summer—comprising a combination baggage and smoking-car, three first-class coaches, observation, parlour and dining cars. All the vehicles are built of steel, and the average weight of the train unloaded is $576\frac{3}{4}$ (U.S.) tons.

In order to meet the demands for fast travelling huge superheated Pacific locomotives have been built for handling all the crack expresses of this system, and they are among the most powerful high speed 4-6-2 engines in the world. Some idea of the locomotive development upon this system during a quarter of a century may be gathered from the fact that these engines are able to sustain a speed of 60 miles an hour with a train load which the engines of twenty years ago could scarcely have moved. It was on this line that the locomotive "999" put up its famous record of covering 10 miles at an average speed of $112\frac{1}{2}$ miles per hour.

The locomotive is 77 feet $4\frac{1}{2}$ inches long over all, which is equal to the total length of the very first train, the De Witt Clinton and its three carriages, which ran upon the New York Central lines. The cylinders are $23\frac{1}{2}$ inches in diameter, and have a stroke of 26 inches, while the driving wheels are 79 inches in diameter. The fire-box measures 108 by 75 inches; the grate area is 56.5 square feet; the total heating surface 3,437 square feet, super-heating surface 823 square feet, the boiler is $70\frac{5}{8}$ inches in diameter at front, and steam is used at



THE "BROADWAY LIMITED" OF THE PENNSYLVANIA RAILWAY EN ROUTE FROM CHICAGO TO NEW YORK.

a pressure of 200 pounds. In running order the engine weighs $134\frac{1}{2}$ tons, while that of the tender loaded is 76.6 tons, representing a weight for the complete locomotive ready for the road of 211.1 tons.

The average train of the "Broadway Limited," which is of similar composition, comprises seven vehicles, all built of steel, and handsomely equipped. Its total weight is nearly 600 tons. It is also hauled by a locomotive of the 4-6-2 type, though the Pennsylvania engines used in this service are of four classes, according to the division over which they operate. All are powerful expressions of the Pacific class with 80-inch drivers and cylinders of 24 inches diameter by 26 inches stroke. The boiler has a minimum internal diameter of 78 inches, with 359 or 368 tubes according to class. The tubes are $250\frac{13}{16}$ inches in length between plates, and the fire-box measures 72 by $110\frac{3}{4}$ inches. The grate area is 55.4 square feet. The external heating surface of the tubes is 4,420.6 or 4,898.4 square feet, and the area of the fire grate 55.4 square feet, bringing the total heating surface to 4,619.9 or 5,097.7

square feet. Steam is used at a pressure of 205 pounds per square inch.

The weight of the engine is 136 or 146.625 tons in running order, of which the weight available for adhesion is 89.75 or 96.625 tons. The weight of the tender in loaded condition is 79 tons, bringing the total weight of the engines of each class to 215 and 225.625 tons respectively.

The "Broadway Limited" is colloquially described as the "Busy Man's Train," and the description is apt. In going west it leaves New York at 2.45 p.m., arriving in the "Windy City" at 9.45 the next morning, before the banks have opened. East-bound it leaves the Middle West metropolis just before luncheon, 12.40 p.m., reaching New York at 9.40 the next morning, again before the banks and business houses have settled down to the day's stride. The train possesses its special features which make such a strong appeal to the commercial interests, being provided with stenographer, library, newspapers, market and sporting reports, terminal telephone, bath, barber, manieurist, and valet service for pressing clothes upon retiring, with afternoon tea presented by the railway company.



A NOVEL COMPARISON.

The huge Pacific (4-6-2) locomotive which hauls the "Twentieth Century Limited" to-day is as long as the first complete train, drawn by the De Witt Clinton, which ran over the metals of what is now the New York Central and Hudson River Railroad system.



THE HUB OF A BUSY RAILWAY.

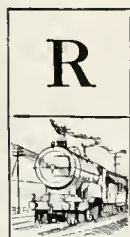
A glimpse of the new Waterloo terminus of the London and South Western Railway.



THE NEW WATERLOO STATION OF THE LONDON AND SOUTH WESTERN RAILWAY.

The Modern Railway Terminus

SOME RECENT DEVELOPMENTS IN STATION BUILDINGS IN LONDON AND NEW YORK



RUSKIN cherished very emphatic opinions of the railway, but his views concerning the average railway terminus would have been far more entertaining. Yet there is no reason why the dead-end of the steel ribbon should be the object for obloquy. The Midland Railway convincingly demonstrated that æstheticism in regard to a railway terminus might be fulfilled quite as completely as with a cathedral when it undertook its St. Paneras station.

For many years the Victoria terminus of the London, Brighton and South Coast Railway was a disgrace to the West End.

When the growth of traffic demanded heroic measures in the provision of additional facilities, the company, instead of following the prevailing fashion of tacking-on kennel-like extensions to an existing dingy structure, decided to provide a building worthy of the situation. It was a costly move, involving an outlay of about £1,000,000, but it was the only possible solution to the problem. Eight acres of land adjacent to the original station were acquired and cleared. The Grosvenor Canal—which abutted and ran parallel with the line—was reclaimed as far as Ebury Bridge. Roads and bridges were raised, and the levels of the thoroughfares leading to the

station adjusted. The street frontage was utilised as an extension of the adjacent hotel, and, executed in a free Renaissance style, now forms an imposing and pleasing entrance. The interior embellishments, so far as they affect the convenience of the public, were planned upon more liberal lines, with spacious booking offices, waiting rooms, etc., while a circulating area of 25,000 square feet was provided to give elbow room for congested business.

From the railway's point of view, the

transformation was more far reaching. Over 18,000,000 passengers use this station yearly, while during the twenty-four hours some 700 trains pass in and out. The expenditure of a million sterling improved the train and platform capacity of the station by 80 per cent. Nine platforms were laid down to serve as many roads, of which four are restricted to local traffic, while by making a platform 1,500 feet in length it is possible to draw two trains alongside of each, so that the capacity of

the terminus is increased to eighteen trains. By providing a third or middle road in the bays, together with crossings, it is possible to bring in or take out a train when the track alongside the same platform is already occupied at the approach end.

Another busy terminus which has undergone a similar upheaval is that of the London and South-Western Railway at Waterloo. The coop-like structure, with its low, drab, miserable roof, which en-



Photograph by permission of the Midland Railway
THE MAGNIFICENT FRONTAGE OF ST. PANCRAS, THE MIDLAND RAILWAY
TERMINUS IN LONDON.



THE SEA OF GLASS FORMING THE ROOF OF THE NEW VICTORIA TERMINUS OF THE LONDON, BRIGHTON AND SOUTH COAST RAILWAY.

closed the platforms of this station for so many years, has gone for ever. Here, again, the fact that traffic had outgrown the capacity of the station was responsible for the transformation. But the station, being situate in a densely populated neighbourhood—one of the most crowded spots in South London, in fact—rendered the roping-in of additional ground exceedingly expensive. Some £2,000,000 were set down as the price for improved facilities, but it was accepted.

The improvement was one of the most sweeping that ever has been attempted in connection with railway termini in Great Britain. To bring it into effect there was a wholesale clearance of streets, schools, chapels, churches, and what not. Hundreds of people were evicted, and the first step

which the railway was called upon to fulfil was the provision of housing accommodation for this dispossessed crowd. Altogether the railway devastated $8\frac{1}{2}$ acres, and thereby brought the superficial area of the terminus to $24\frac{1}{2}$ acres.

The number of approach roads were increased from four to eleven, and these, immediately outside the station, spread out fan-wise to serve 23 platforms with 30 roads. The requirements of the public were borne in mind in planning the new terminus, inasmuch as the grouping of the platforms, serving different classes of traffic, is carried out upon rational lines, the circulating area is enlarged, while the railway administration itself is provided with ample accommodation for carrying out the intricate



AN INTERIOR VIEW OF VICTORIA STATION.

This photograph gives some idea of the enormous length of the platforms.

work associated with a busy and popular railway.

But if one desires to realise what can be accomplished in railway terminus planning, one must go to the United States, where striking works of this character are offered. Previous to the year 1900 all but one railway were deprived of a footing in New York City. The other trunk lines came to a dead end on the western banks of the Hudson River, and the passengers had to negotiate this waterway by ferry. The Pennsylvania Railroad suffered seriously under this handicap, and in view of the fact that the aggregate of people handled by the ferries had risen from 59,000,000 people in 1886 to 140,000,000 people in 1906, it resolved to establish its terminus in the Empire city of the Empire state; to abolish the ferries so far as passenger business was concerned in favour of tubes. The latter were successfully completed by a British engineering firm, and simultaneously the raising of the large and

architecturally magnificent railway station was taken in hand.

For this purpose a vast tract of land was laid waste, offices, houses, and a host of other buildings of a varied description being swept away. In fact, it was the biggest individual clearance of occupied land in the history of the city. When this task was completed, the company excavated the site to a depth of some 50 feet to bring the tracks below the street level, so as to gain easy entrance to the tubes laid beneath the Hudson River.

The Roman Doric style was selected for the building. It occupies practically a huge square block 788 feet 9 inches in length by 799 feet 11½ inches deep. The whole of the building, which covers 8 acres and has a maximum height of 153 feet, is devoted to the requirements of the public and the handling of the trains, there being no superstructure in the generally accepted sense of the word, such as for the provision of administration offices or a hotel. The

main waiting-room is 314 feet 4 inches in length, 108 feet 8 inches in width, and 150 feet in height, while there are a number of smaller waiting rooms, baggage rooms, telephone and telegraph offices—in fact, every possible convenience that the public can desire. Travertine stone, of which imperial and modern Rome is built principally, entered largely in its construction, the requisite material being imported into the States for the first time for building purposes from the quarries in the Roman Campagna, near Tivoli, Italy.

One conspicuous feature concerning this terminus is the number and spaciousness of the entrances and exits, both for foot and vehicular traffic, so that the minimum of time is occupied in passing in and out of the station. Moreover, the incoming and outgoing traffic above the train platform

level is completely separated, so that no confusion can arise. The northern side of the terminus is assigned exclusively to the Long Island Railway, which is a subsidiary of the Pennsylvania Railroad, and being equipped with distinct booking offices, entrances, and exits, this heavy suburban traffic does not come into contact with that of the main line.

The tracks are placed 36 feet below the street level, and for the first time upon an American trunk railway the English raised platform, enabling one to step in and out of the cars without climbing, was adopted. There are 11 passenger platforms, and to expedite movement these are fitted with 25 baggage and express lifts. In addition to the station there is a vast yard, the whole covering no less than 28 acres. The yard has 16 miles of sidings, capable



ANOTHER INTERIOR VIEW OF VICTORIA STATION.



THE MAGNIFICENT NEW YORK CITY TERMINUS OF THE PENNSYLVANIA RAILROAD.

The building covers a huge block 788 feet 9 inches long by 799 feet 11 $\frac{1}{4}$ inches deep. The 21 roads are 36 feet below the street level.

of holding 386 vehicles. The aggregate length of the 21 standing tracks in the station is 21,500 lineal feet. Over 150,000 cubic yards of concrete were used for the retaining walls, foundations, street bridging, and sub-structure. The station building is supported by 650 masonry columns, the greatest weight upon one of which is 1,658 tons. The exterior walls of the terminus aggregate 2,458 feet—nearly half a mile—in length, and 490,000 cubic feet of pink granite were used in their erection. Altogether, 550,000 cubic feet—47,000 tons—of this granite were utilised in the construction and ornamentation of the pile, in addition to 27,000 tons of steel, and 15,000,000 bricks, weighing 48,000 tons. The undertaking, from the arrival of the housebreakers to clear the site until

the station was ready to receive trains, occupied six years, while the whole of the masonry was completed in approximately thirteen months.

The consummation of this daring project was due to one man—Alexander Johnston Cassatt. From the moment he assumed the reins of the Pennsylvania system he decided to establish his railway in the centre of New York City, although it cost £23,000,000 to do it.

Within easy reach of the Pennsylvania terminus has arisen another stately pile devoted to the exigencies of a busy railroad. This is the Grand Central station of the New York Central and Hudson River Railroad. Four times has this great railway been called upon to overhaul its New York terminus. In the early days this railway was not

permitted to run its trains in and out of the station by steam power. The cars had to be hauled in and out by horses, and the difficulties attending such a crude system may be imagined, especially during the terrifying blizzards of winter.

This road suffers under one serious handicap. All traffic has to be handled over four tracks extending through tunnels. With the dawn of the present century it was realised that further facilities would have to be provided. Some 46 acres of ground were required, and the chief engineer of the road, Mr. W. J. Wilgus, suggested the most startling scheme that ever has been attempted in railway terminus engineering. As the land in the immediate vicinity of the station is so valuable, he

suggested that the tracks should be depressed, disposed upon two levels, and that, when completed, the upper level should be enclosed. Then he proposed that upon this roof streets should be laid out, and huge buildings erected for the benefit of commerce, private residential purposes, and pleasure. He admitted that the cost would be prodigious, but he emphasised the fact that the revenue accruing from the letting of the buildings would represent a remunerative interest upon the outlay.

The scheme, notwithstanding its unusual and daring character, was approved. No fewer than 68 tracks were provided, disposed on two levels, and all converging to the four tracks leading out of the city. The lower level is devoted to suburban



THE MAIN WAITING ROOM OF THE NEW YORK CITY TERMINUS OF THE PENNSYLVANIA RAILROAD.

traffic, which is handled over 27 roads, while the upper level is exclusively used for express passenger service, for which 41 tracks are provided. The whole site of 46½ acres had to be excavated to an average depth of 45 feet, and the digging of this huge pit involved the removal of 3,000,000 cubic yards of soil, mostly rock, which had to be hauled from 10 to 25 miles away to be dumped. In this depression massive columns and beams had to be set in position to offer a solid foundation for the express track level, which task alone absorbed over 60,000 tons of steel. Above this viaducts and bridges had to be erected in order to restore the intercommunication of the city, and everything had to be accomplished under traffic conditions so that the railway services might not be hampered one tittle.

Work was commenced on the east side of the old structure and completed section by section westwards. By the time the two levels had been completed 32 miles of new roads had been laid, and the greater part of the express level roofed over ready to receive skyscrapers, hotels, boarding houses, clubs, theatres, and so forth. These are to be let upon long leases—probably 99 years; and by the time this superstructure work is completed not a vestige of the railway, with the exception of the two chimney stacks of the power house in one corner, will be visible. As the railway traffic is worked entirely by electricity no difficulties in operation will be experienced, and the whole of the buildings erected overhead will derive light, heat, and power from the existing power station.

Externally the façade of the building is massive and imposing. There are four levels—the street-level gallery, the express level, the suburban level, and below that a level for handling all baggage. Staircases have been abolished, as they induce congestion. In their place are easy sloping inclines, or “ramps,” having a rise of

8 in 100 feet. The circulating area for inbound trains comfortably holds 8,000 people; that for outbound trains, 15,000; and the commodious waiting room accommodation a further 5,000 persons. Altogether it is estimated that the terminus will hold 30,000 people without crowding, while 70,000 people are able to pass through it hourly in safety and comfort. The arrangement of the tracks enables 200 trains to be handled per hour, this capacity being achieved by the introduction of a loop system whereby incoming trains on both levels, after discharging their passengers, can swing round to run into the yard at one side to await the next call for service. This particular project is probably the most expensive undertaking of its type which ever has been attempted, inasmuch as the total cost of the scheme will be in the neighbourhood of £30,000,000.

Possibly the most extraordinary railway terminus is that of the Hudson and Manhattan Railroad, colloquially known as the “Hudson Tubes,” ^{The} “Hudson Tubes.” offering communication between lower New York and the New Jersey shore, and incidentally serving three big railways. Its down-town terminus in the metropolis is at the corners of Cortlandt, Dey, and Fulton Streets. The station is underground, entirely below the level of the sea, and is flanked by a reinforced concrete wall 8 feet in thickness to protect it from inundation. The space enclosed is 95 feet in depth by 185 feet wide, and over 400 feet in length. This accommodates the railway tracks. Immediately above this is the grand concourse, having a superficies of 2 acres. Above this rises a gigantic skyscraper, towering 22 floors into the air, the whole of which is occupied by more than 4,000 offices, the superficial area of which exceeds 50 acres.

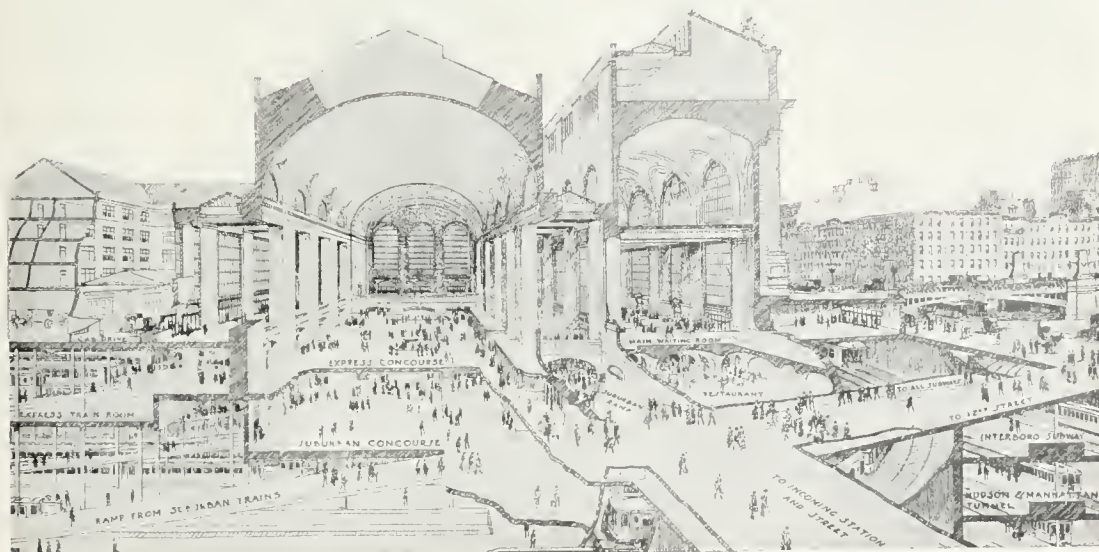
In the erection of this building more than 26,000 tons of steel and 16,300,000 bricks were required. Not only is the Hudson Terminal Building one of the sights of the

city, but it is also one of its busiest hives of industry, inasmuch as it is the New York home of all the leading industrial organisations of the United States. During the day its population would do credit to a country town, since it numbers over 10,000 souls, while more than 55,000 people pass in and out of the offices daily in addition to the 100,000 people who use the station in the basement. The skyscraper is the property of the railway, and the gross income from the rental of the offices alone represents over £320,000 per annum.

The provision of huge costly buildings for railway terminus purposes is by no means confined to the city of New York. Chicago, which is the busiest railway centre in the world, is contemplating a scheme for concentrating its scattered railway stations which will eclipse anything previously attempted. It is recognised as being hopelessly impossible to house all the roads beneath one roof, owing to the colossal number of people which would have to be handled. Accordingly, an alternative proposal has been discussed. This is the clearing of a huge tract in the city

and the disposal of five or six mammoth stations side by side—a street of railway termini. At the moment the finest terminus in the “Windy City” is that completed in 1911 by the Chicago and North Western Railway at an expenditure of £4,750,000. While it does not compare in magnitude with those to be found in New York, yet probably it is the most expensive and most luxurious building for the business which it is called upon to handle. The building covers 69,760 square feet, contains 8 platforms serving 16 roads, and handles 55,000 passengers using 320 trains, which pass in and out daily.

Virtually it is a huge hotel, everything incidental thereto being provided, with the exception of sleeping accommodation. There are private suites of apartments for ladies and children, comprising boudoir, tea rooms, bath and dressing rooms, dining saloons, emergency rooms, with full staffs of skilled nurses, chemist's shop, gentlemen's dressing rooms, hairdressers, mannequins, boot cleaning, lounge and smoking rooms, while last, but not least, is a large, well-equipped garage.



By courtesy of the "Scientific American."

VERTICAL SECTIONAL VIEW OF THE NEW GRAND CENTRAL STATION OF THE NEW YORK CENTRAL AND HUDSON RIVER RAILWAY, SHOWING THE TWO TRAIN LEVELS.



Photograph by permission of the Canadian Northern Railway.

GRADERS AT WORK UPON THE TÊTE JAUNE CACHE-KAMLOOPS (B.C.) SECTION OF THE CANADIAN NORTHERN TRANSCONTINENTAL

How Two Men Built a Trans-continental Railway

THE ROMANTIC STORY OF SIR DONALD MANN AND SIR WILLIAM MACKENZIE,
AND HOW THEY FOUNDED THE CANADIAN NORTHERN RAILWAY SYSTEM



CANADA has been productive of many brilliant men, but none occupy so much of the world's limelight as a trio of railway builders. These are James J. Hill, Sir Donald Mann, and Sir William Mackenzie. "Jim" Hill dreamed of railway conquest before Canada was ripe for it, and accordingly shook the dust of his homeland from his feet for the United States, where there was unbounded scope for his energies. The extent of his success is realised to-day,

because he has built up some of the greatest and richest systems of new roads in the history of the steam locomotive. "Dan" Mann and "Bill" Mackenzie came later, when the Canadian West was just awakening. Both saw the opportunity and both grabbed it with a tight and heavy hand.

The two "M's," although partners, are as diametrically opposite in their characters, temperament, physique, and methods as the two poles. Although to-day both have received handles to their names in recognition of "something attempted something

done," both still are known up and down the grade as "Dan" and "Bill." The grader would spurn the idea of addressing his former comrades as "Sir"; it would represent an impassable gulf for that free discussion and ventilation of opinions around the camp fire which has built up the reputations of these two railway builders. "Dan" is thew and muscle, with a well-developed canny corner in his head—the heritage of his Scottish descent—who is more at home in the rough-and-tumble of the field, who prefers the shack to the drawing-room, and who would rather swing an axe, pick, or a shovel than a golf club or a tennis racquet. "Bill," on the other hand, is the lightning calculator and man of figures, who can juggle with millions as easily as his colleague can toss earth and rock about, who is more at home at the desk in the heavily carpeted office, and who, by force of words, can get his own way and the sinews of war to enable his partner to fulfil their mutual dreams.

Both have romantic and interesting histories. Sir Donald Mann was broken in to agriculture upon his father's small farm in lower Ontario, and was destined for the Church.

But at seventeen he quitted the parental roof and made his way to Michigan, where he became a lumber-jack. His strength, physique, and hardened constitution suited him to this grinding task, and he kept at it until the Canadian Pacific thrust its steel nose into the Canadian West. The railway wanted timber for a thousand and one purposes, and the young lumber-jack saw dozens of men who knew nothing about lumber, who could not swing an axe, and who had no capital, become wealthy within a few months by buying timber cheaply and selling it dearly to the railway. Young Mann accordingly decided to plunge into the same game. He tendered a contract for sleepers, and got it. This initial success prompted him to indulge in railway building, but he hesitated be-

cause he knew nothing about the engineers' way of sizing up facts and figures. This difficulty he overcame by chumming with one of the young railway engineers, and in a short time he mastered the intricacies of figuring up cubical contents of embankments and cuttings. Then he boldly attacked some of the most difficult sections of the line, and in this manner got as far west as the tumbled interior of British Columbia.

When the Canadian Pacific was finished he was persuaded to take over a railway contract in Chile. He went, but the "Land of To-morrow" and the lackadaisical methods of the South American navy so worried him that he returned home in disgust. Thence he went to China in the anticipation of securing a big concession, but the ways of the wily Chinese were beyond him; so, after a narrow escape from a duel with a Celestial dignitary whom he had offended over the deliberations, he returned home once more. At that moment mining in British Columbia was proving highly profitable, so he threw himself into this field, and proved eminently successful.

Meantime, young Mackenzie had been passing through his peculiar mill of experience and drudgery. He was born in an insignificant back-woods' village in Toronto, and when he started upon his career his horizon was limited. He took a humble, poorly-paid position as a school-teacher, but drilling the young was an irksome occupation with no future. The lumber industry was booming, and he drifted into a lumber town, where he established an unpretentious business, supplying the limited and varied necessities of the lumber-jacks. Storekeeping likewise proved a tame investment, so with the few dollars he had saved he set up a saw-mill, to cut up logs for the Canadian Pacific Railway. As the steel band penetrated farther and farther west, Mackenzie went with it, until at last he also found himself in the heart of

Sir Donald Mann.

Sir William Mackenzie.

British Columbia. Here Mann and he met frequently in their commercial transactions, and bandied experiences and reminiscences around the camp fire. When the Golden Spike of the Canadian Pacific Railway was

its ambitious project. Accordingly it languished until, one day, Mann stepped in, and by dint of bargaining exchanged his life savings for the derelict charter.

Now he had to raise the money to build



Photograph by permission of the Canadian Northern Railway.

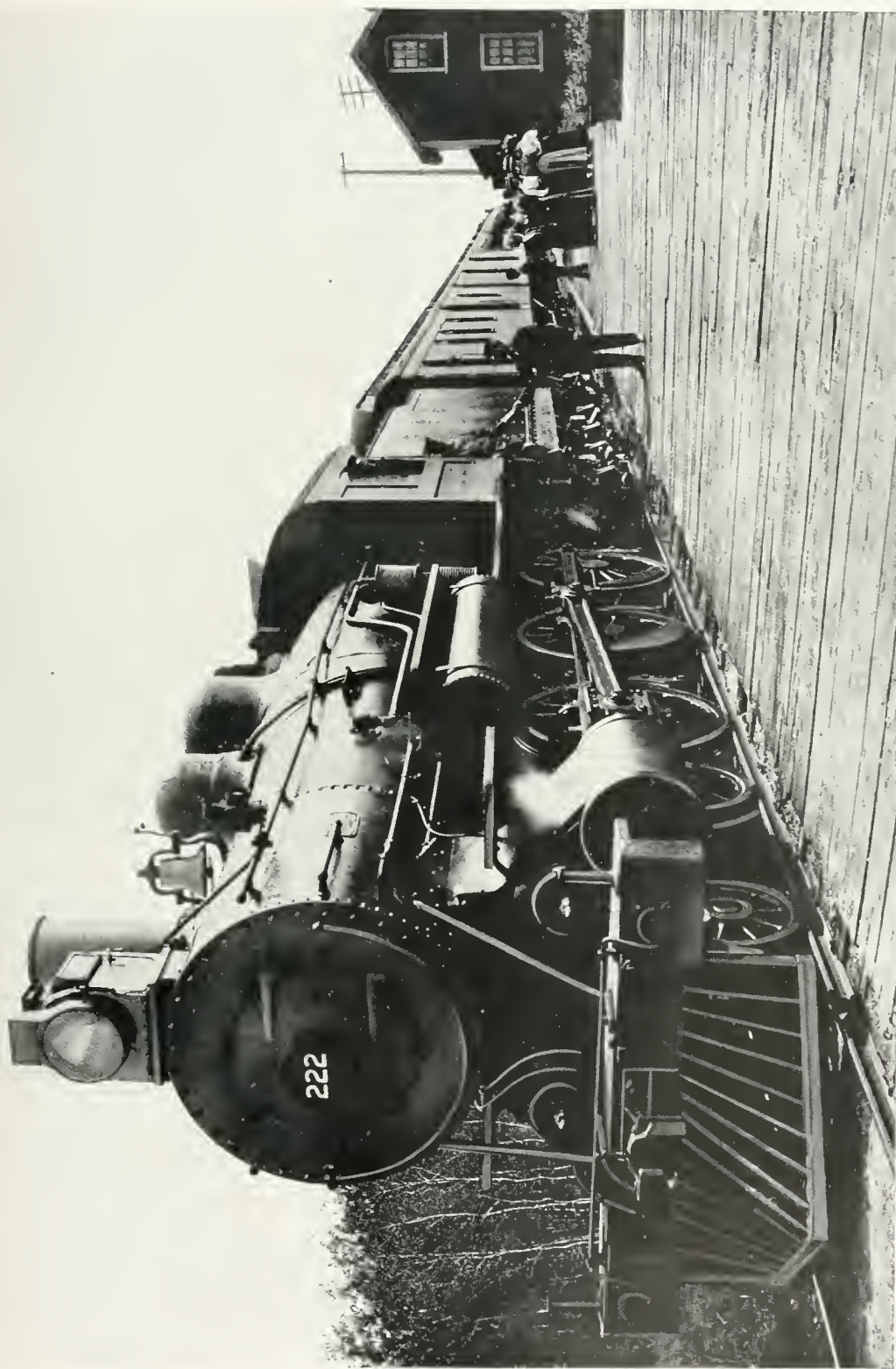
BUILDING A TEMPORARY TRESTLE BRIDGE IN NORTH SASKATCHEWAN.

driven, and the camps broke up, each of this twain went his own way.

It was not until the middle 'nineties that the two came together once more. Young Mann, having disposed of his mining properties in British Columbia, wandered east and happened to hear that a company had secured the charter to build a line from Portage la Prairie, 44 miles west of Winnipeg, to Lake Winnipegosis. Mann had been contemplating, in his own quiet way, the idea of starting a new railway, but somehow or other things had not fashioned themselves to his line of fancy. Suddenly he learned that the Lake Manitoba Railway and Canal Company was in difficulties. The concern possessed plenty of initiative but no wherewithal to carry out

the line. Despite the croakings of his friends, who warned him that he would meet disaster, he decided to make a bold plunge. He went east and laid his plans before the Bank of Montreal. He was known to them, but, after he had completed his vivid pictures of the future awaiting such a pioneer road as he proposed to lay down, they refused to advance a penny unless he could find a partner.

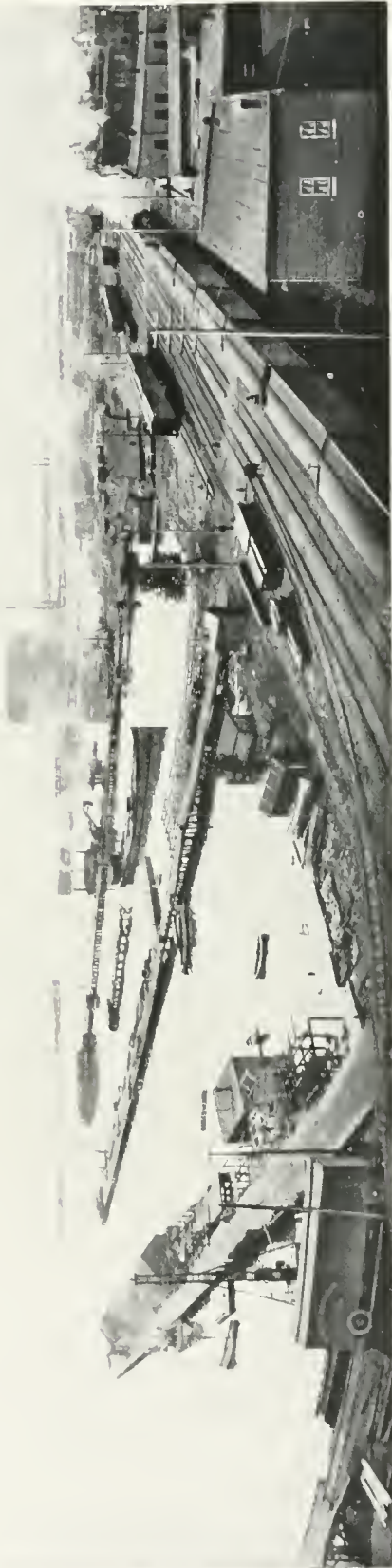
This seemed an insuperable obstacle to Mann, but Dame Fortune assisted him. That night, as he boarded the train for Toronto, he tumbled into Mackenzie, whom he had not seen since they parted in British Columbia. Mann unfolded his ideas to Mackenzie. The latter became enthused,



Photograph by permission of the Canadian Northern Railway

STANDARD CANADIAN NORTHERN PASSENGER TRAIN RUNNING OVER THE MAIN LINE BETWEEN PORT ARTHUR AND EDMONTON.

The locomotive is of the Pacific type.



A VIEW OF PART OF THE HARBOUR OF PORT ARTHUR, THE LAKE TERMINAL OF THE CANADIAN NORTHERN RAILWAY AT THE
Photograph by permission of the Canadian Northern Railway

and the next day a partnership was drawn up between them.

Mann was now ready to tackle the bank again, but as Mackenzie was more adept at financial transactions he was entrusted with this delicate task. But while Mackenzie was wrestling with the financiers, Mann made another move and effected a smart coup. He persuaded the Manitoba Provincial Government to guarantee the new line to the extent of £1,600 per mile. Although such subsidies had been extended to company-owned lines, it represented quite a new and novel departure to assist a privately-owned concern in such a way. This achievement inaugurated what has since become a big policy of the Mackenzie-Mann railway system, otherwise known as the Canadian Northern Railway, and has been continued up to this day.

The sinews of war being settled, construction was commenced. In 1896 the metals were laid from an obscure village known as Gladstone, to a dot on the prairie 100 miles distant. At that time the end of steel did not even boast a shack, but in anticipation it was christened Dauphin, which to-day is a flourishing town.

It was an unpretentious beginning. Eighteen cars and three locomotives sufficed for handling all the traffic, while the service was two trains each way a week. Thirteen men and a boy comprised the whole of the railway staff, and £30 a week sufficed to defray all wages. Yet during the first year the little line earned no less than £12,000, and a handsome surplus remained after all charges were met. Although the outlook certainly was rosy, Mackenzie suggested that the railway should be leased to a company, and that they

should concentrate their energies elsewhere ; but Mann would not hear of such a thing, and so a tight grip was kept upon it. As things turned out, Mann's grim insistence was a fortunate circumstance.

That 100-mile stretch of line was the foundation of the Canadian Northern system which to-day embraces some 5,000 miles in actual operation, besides hundreds of miles which have been plotted or are under way. Having obtained a good start, the two "M's" went steadily ahead, adding to their system throughout the prairie provinces at the rate of a mile a day, and this pace was maintained for a matter of seven years.

In this phenomenal rise the young railway was able to take advantage somewhat of the railway situation as it prevailed in Canada in those days. Odds and ends of different lines were built when the boom was on. Some proved profitable undertakings ; the majority did not. The older railways, where the conditions were favourable, leased or bought these streaks of rust and turned them to useful account. Then if such a road failed to prove profitable it was dropped promptly when the lease expired. The two "M's" followed this tendency very closely. In one instance the Canadian Pacific Railway leased 250 miles of a junk railway in Saskatchewan. The lease was nearly out, and it was accepted as a foregone conclusion that it would be renewed. But to everyone's surprise the first transeontinental did not want it. Still, the lease was taken up : Donald Mann acquired it before others had grasped the situation.

In this manner the Mackenzie-Mann interests were able to extend their influence from the eastern limits of the Rocky Mountains to the shores of the Atlantic. A derelict railway which could scarcely afford to keep the weeds off its track found a purchaser—at a price—in the two railway builders. But the latter had no

intention of running these isolated links. They immediately set to work to connect one with the other, thereby securing a continuous steel road across the Dominion, which within the near future will have one end resting on the Atlantic and the other on the Pacific seaboard.

On paper this policy of acquiring existing lines, and then constructing communicating links, so as to build up a transeontinental railway, appears to be very simple and inexpensive, but in grim reality it has proved somewhat formidable. The roads which were purchased were built and sufficed to serve extremely limited local needs, and for the most part were laid through physically easy country, the promoters of these small undertakings shrinking from any effort to accomplish startling work. Thus, for instance, in the east the Canadian Northern was confronted with the spanning of a gap extending through the ragged, unremunerative country of Ontario which harassed the builders of the Canadian Pacific Railway so sorely. Some 500 miles of the hardest construction it is possible to conceive had to be undertaken where there is no sign of local revenue—at least not for many years to come.

Before this bold step was taken the railway secured a foothold upon the Great Lakes at Port Arthur. In fact, the present prosperity of On the Great Lakes. this lake-port is due entirely to the Mackenzie-Mann initiative. When the Canadian Pacific Railway was built a divisional point was established here, together with portal facilities to link up with the lake traffic. But the municipal authorities of the young town grew somewhat avaricious, and considered the transeontinental railway in the light of the goose with the golden eggs. The railway tolerated the situation until at last it declined to be assessed another cent, and threatened to remove to Fort William, four miles west, if their interests were not considered favourably, but the town regarded this as

a bluff. Thereupon, one day, the Canadian Pacific commenced to move its establishments to the old Hudson Bay post, and Port Arthur sank into obscurity while Fort William rose rapidly, until the Cana-

to the Pacific?" The difficulties which the Canadian Pacific experienced in traversing the rugged mountain ranges were still vivid; while the fact that the Government had discovered an easier route farther to



Photograph by permission of the Canadian Northern Railway.

TYPICAL BRIDGE PROVIDED FOR THE CROSSING OF THE WIDE WESTERN CANADIAN RIVERS.

dian Northern decided to step into the blank caused by the rival's action.

When the activities of these two railway builders were confined to the prairie provinces they carried their lines as far west as Edmonton, the provincial capital of Alberta, threading some of the richest and most fertile country west of Winnipeg. Having effected a foothold in the east, and being determined to connect the latter with their western roads, it is not surprising that these two enterprising spirits turned their eyes farther west and contemplated the possibility of carrying their tracks through the Rockies to the Pacific.

The question arose, "How can we get

the north in the 'seventies through the energies of Sir Sandford Fleming was still fresh in their minds. Why not extend westwards over the route plotted by Sir Sandford Fleming? It appeared to be quite a feasible proposition, especially as the Fleming route was overwhelmingly easier than that actually followed by the first transcontinental. The more the subject was discussed and dissected the more enthusiastic the two railway builders grew. From Edmonton to the Yellowhead Pass was a matter of some 250 miles, while thence to tidewater *via* Kamloops was another 350 miles approximately.

Before this route was accepted definitely,

however, bands of surveyors were sent out into the field to probe the Rockies, to discover, if at all possible, a still easier pass through the range. These surveyors trekked as far north as the Peace and Pine River passes, but ultimately it was decided that the Yellowhead was the most suitable to the scheme. Consequently it was adopted.

The going west of Edmonton has been heavy and expensive, especially from the

point where the Rockies are entered at the gap where the

Athabaska debouches from the range. Heavy side-hill excavation and embankments have been found unavoidable, while the premium upon dynamite and steam shovel has been exacting. But the fact that construction was certain to be costly had been realised in the beginning and arrangements completed accordingly. The first move was to enlist the assistance of the Province of British Columbia. This Government responded handsomely by granting a guarantee of £7,000 per mile through its territory.

The one great advantage of the Yellowhead Pass route is the low maximum gradient which is offered through the mountains. At no point will the locomotives be called upon to face a climb stiffer than 52.8 feet per mile. Descending from the Pass, through which it double-tracks the Grand Trunk Pacific as far as Tête Jaune Cache, it swings to the south to traverse the length of a fertile narrow valley as far as Kamloops. Here it bends to the left, and in company with the Canadian Pacific Railway makes its way to the coast.

It is the section between Kamloops and tidewater where the heaviest constructional work is being encountered. The Canadian Pacific clings to one side of the Thompson and Fraser Rivers, while the youngest Dominion transcontinental hugs the opposite banks of the waterways. The shoulders and spurs of the peaks which thrust themselves into the rivers are being either

pierced, trimmed back, or blasted clean out of the way, so as to afford a road for the rails.

It was estimated that some £5,000,000 would have to be expended upon the mountain division between Edmonton and tidewater. The grade was attacked all along the line. While armies of navvies pushed their way westwards from Edmonton, another army concentrated at Kamloops, divided, one moiety pushing northwards towards Tête Jaune Cache, while the other drove westwards along the riverside.

In order to maintain communication between the camps scattered over 100 miles along the Thompson River one contractor brought up boilers and engines in pieces, which were reassembled in a small light-draught steamer which was built and launched near Kamloops. This plied up and down the waterway with materials and supplies. Horses and vehicles of all descriptions were brought in and shipped to the various camps. At Yale two large gangs attacked each side of a shoulder of dense rock to drive a tunnel 2,070 feet in length, while another work of a similar character had to be taken in hand in the Black Canyon, near Ashcroft.

Whereas the Canadian Pacific and the Grand Trunk Pacific lines run into the city of Vancouver, the Canadian Northern has established its own **A New Port.** terminal at Port Mann upon the estuary of the Fraser River, near Vancouver. With an approach channel carrying 60 feet of water, the new port will be available to the largest sea-going vessels. This decision was wise, because it ensures ample elbow-room for future developments and extensions. When the port builders arrived the site was covered with dense bush, but within a few months the whole of this was cleared off, a landing stage erected to enable material for the new railway to be unloaded, the streets pegged out, and the sections of land divided into plots for building purposes. Tents and

timber shacks grew like mushrooms, and already are disappearing in favour of substantial and permanent structures. The Canadian Northern Railway has vast commercial interests of a diversified character at stake in British Columbia. They represent an investment of some £6,000,000, give employment to 6,000 people, and have a gross turnover of about £2,000,000 per annum, so that there is a vast business awaiting the completion of the facilities at Port Mann. An initial area of 250 acres along the water front was cleared to admit of the construction of buildings for the railway, while an additional 600 acres along the river bank have been roped in for a similar purpose.

Another huge undertaking which this young railway has in hand is the driving

of a tunnel, three miles in length, through Mount Royal in order to gain access to the city of Montreal and the docks and water front. Not only will the railway obtain an excellent entry into the city in this way, but it will solve a complex intra-mural problem. Montreal has been handicapped in its extension by the existence of the mountain, but the Canadian Northern, by means of its tunnel, will open up a new residential area. Behind the mountain a model city is being laid out, and the tunnel will offer a short and quick link of communication between the city and this suburb. Emerging from the tunnel the railway will cross the city over an elevated line to the water front. By the time this work is consummated about £5,000,000 sterling will have been spent.



Photograph by permission of the Canadian Northern Railway.

DRIVING THE TUNNEL THROUGH MOUNT ROYAL TO GIVE THE CANADIAN NORTHERN
ACCESS TO MONTREAL.



Photograph by permission of the South African Railways.

HOW THE HEAVY COAL TRAINS ARE LIFTED OVER THE 1 IN 30 BANKS UPON THE NATAL SECTIONS OF THE SOUTH AFRICAN RAILWAYS.

Three locomotives, one at each end and another in the centre, are used.

The Railway Network of South Africa—I

HOW THE STATE GOVERNMENTS ACQUIRED AND DEVELOPED THEIR RAILWAYS

WHEN the weaving of the network of steel throughout South Africa was commenced there was no bold project such as accompanied the railway settlement of Canada. In those days the country possessed no more attractions than Alaska. Its mineral wealth remained to be discovered; it was held to possess little or no agricultural value, and the forbidding rugged lofty mountain range which presses upon the shore line scared those who were quite prepared to father a railway scheme.

It was not until the late 'fifties that railway building was entertained seriously.

The issue was raised by a private concern styled "The Cape Town Railway and Dock Company," which in 1857 received the requisite government sanction to embark upon the railway conquest of the territory. The move was far from being ambitious. The promoters proposed to drive the band of steel inland from the sea to a point known as Wellington, a distance of 57 miles. Possibly the promoters of the scheme entertained visions of being able to push farther northwards into the country, and ultimately be in a position to provide a trunk road. At all events the policy was correct, inasmuch as to-day this initial section forms part and parcel of the main



road which runs from Cape Town to the distant interior via Kimberley, Buluwayo, and the Victoria Falls, forming the Cape-to-Cairo backbone of the continent.

Two years elapsed after the franchise was granted before actual construction commenced, the first sod of the pioneer railway in Cape Colony being turned in 1859. The builders followed the easiest pathway through the coastal barrier, although even then they had to lift their metals to an altitude of 630 feet in the course of some 35 miles. Some three years' toil saw the line carried into Wellington, and it was opened to the public amid considerable rejoicing in 1863.

The effort to provide Cape Colony with railways stirred interests in the adjacent colony of Natal. An unpretentious company known as the "Natal Railway Company" decided to commence the grid-ironing of that country. But their ambitions were even more modest than their colleagues next door. They sought a charter to build only six miles of line! And the first instalment was for only two miles! The fulfilment of this momentous undertaking was accomplished in 1860 by the connection of Durban with the wharf, or, as it is known more generally, the "Point."

Those were strenuous times in the history of the country's railways. The general manager was secretary as well, and although the road between the two extremities of the humble line was knee-deep in sand, the directing force apparently nursed such a poor opinion of his railway that he always made the journey on horseback in preference to the train. He was a Portuguese gentleman, and the essence of courtesy. The staff worked diligently and conscientiously, but it was quite a common circumstance for their wages to be twelve months in arrear! When the patient toilers approached the manager for money he never failed to send something on account, with the hope that he would be able to remit the balance

after he had scoured round and collected accounts. Still, they always received what was due to them in the end, which fact doubtless accounts for the loyalty they manifested towards the undertaking.

Some fourteen years later this struggling company decided to complete the second part of its original project. This was the laying of the metals from Durban to a point 4 miles distant on the Umgeni River, and this section was opened for traffic in 1874. From this sudden display of activity one might imagine that the company had struck a run of exceptional prosperity and was in an affluent condition. But it was not so. The company struggled against overwhelming odds for another two years, and then was bought out by the Government, which had decided to provide the country with railways, for £40,000.

The company in the neighbouring Cape Colony had fared little better. It led a hand-to-mouth existence. Beyond an extension of $5\frac{1}{2}$ miles to what is now the popular resort of Wynberg no further construction was undertaken. In fact, it was as much as the whole system of $63\frac{1}{2}$ miles could be kept going. Private interests refused to be attracted to the railway possibilities of the country, and this scarcity of funds at last induced the Cape Government to step in. It acquired the line, and forthwith decided to develop the railway under government auspices.

When these two pioneer lines in the respective colonies were built the Stephenson gauge of 4 feet $8\frac{1}{2}$ inches was adopted. But when the two governments secured control they concluded independently that such a gauge was too expensive for South Africa. Opinion that a gauge of 3 feet 6 inches would be quite adequate was emphatic. Forthwith this gauge was adopted, and to-day is regarded as the standard in British South Africa. One of the first moves consummated by the Colonial Governments when they secured

Natal's
Develop-
ment.

The
Gauge
Question.

the existing properties was to convert them to the narrower gauge. This decision has been assailed vehemently in certain quarters during recent years, but the

Tullagh, when they turned and swung south-eastwards to reach Worcester. This involved a detour of some 80 miles, whereas the airline between Muldersvlei and



Photograph by permission of the South African Railways

MAKING A DEEP CUTTING IN NATAL.

Native labour is extensively employed in construction.

wisdom of the policy followed at the time cannot be assailed, since no one contemplated the discovery of diamonds, gold, and other minerals in the interior.

Both Cape Colony and Natal outlined a comprehensive system of extensions after becoming railway proprietors. The first-named immediately pushed forward from Wellington northwards. Owing to the configuration of the country, the pioneers upon reaching Muldersvlei had been compelled to make a swing due north. The government continued this alignment as far as

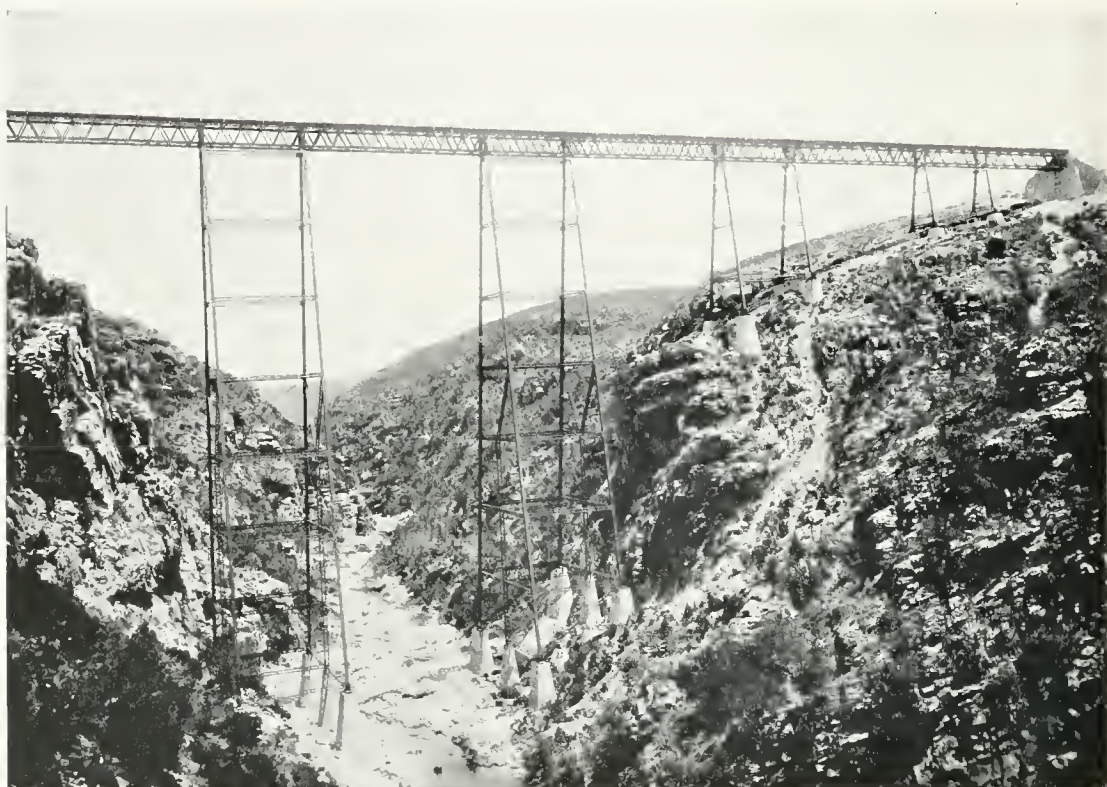
Worcester is approximately 40 miles. But the location never has been revised, which tends to prove that the pioneers laid out their line with commendable skill.

It was the discovery of diamonds in Griqualand West in 1872 and the coming of Kimberley which stimulated the government programmes. Cape Colony resolved to reach the diamond town with all possible speed, while Natal decided to stretch as far in that direction as it could. The Cape Government drove its way onward from Worcester, and in its haste, instead of

carrying the ribbon of steel through the most fertile stretches of the country, where local traffic might have been developed throughout every mile, it struck across

achieved within less than ten years, took a long breather.

But in consummating this achievement the engineers had accomplished some strik-



Photograph by permission of the South African Railways.

THE LOFTY STEEL VAN STAADENS BRIDGE, NEAR PORT ELIZABETH.

The photograph conveys a striking idea of the rugged character of the country.

the fearsome Karoo. But for the discovery of diamonds it is a moot point whether the existing route ever would have been plotted, since the arid stretch is absolutely useless from the economic point of view; certainly private enterprise never would have essayed to span it. Simultaneously two other trunk lines, having their seaboard terminals at Port Elizabeth and East London respectively, were taken in hand, to be carried to a common inland objective—Diamondopolis. Kimberley leaped into fame, and was to become one of the greatest inland points in the country with three outlets to the seaboard; the railway reached it in 1884, and then the Cape Government, satisfied with what it had

ing work. At Worcester the line was at an altitude of 800 feet. Immediately confronting the engineers was the hard pull to the top of the great inland plateau, the edge of which, unfortunately, is somewhat searred and ragged. Within some 40 miles of the foregoing railhead the metals had to be lifted 2,400 feet, followed by a sharp drop to 2,530 feet, when came another immediate ascent to 3,600 feet at Laingsburg. At Dwyka River, about 240 miles from Cape Town, the level falls to 1,520 feet, from which point the ascent to the highlands proper commences, a height of 4,580 feet above sea level being registered at Biesjespoort, 400 miles out of Cape Town. In the course of the succeeding 175 miles

the railway falls 1,080 feet, when comes a rise of 580 feet in 25 miles to Graspan at the 600th mile-post, followed by a descent of 420 feet in a similar distance to reach Kimberley, 625 miles from Cape Town, lying at an altitude of 3,660 feet.

As may be supposed, in laying the earliest lines first cost was kept down very religiously, because there was no blinking the fact that for years the lines could not hope to prove remunerative. The grades in places were heavy, while the curves were sharp. Labour difficulties, combined with the haste in construction, contributed in a certain measure to rough construction. In fact, the trunk line was nothing more nor less than a pioneer road capable of being improved as traffic grew heavier. Water was another problem which occasioned quite ingenious thought time after time, especially on the arid stretches of the desert. In some instances water trains had to be maintained to provide requirements for the locomotives. Protection against shortage of water, however, is now ensured by the provision of storage dams, bore-holes, and the installation of pumping plants, so that even the longest and driest periods of the year are viewed with absolute equanimity.

Although construction was brought to a comparative standstill once Kimberley was reached, yet considerable work was accomplished. Feeders were thrown out here and there, tapping promising country within a few miles of the main lines. The latter, too, were taken in hand as the traffic increased, being regraded and virtually rebuilt. This work of improvement is still in active progress, as the railway expansion of the country is proceeding rapidly.

Whereas 60-pound rails were used for the trunk lines, 80-pound rails are now being laid, the displaced lighter metals being utilised upon branch lines.



Photograph supplied by the South African Railways.
EXPRESS CROSSING THE IFABA BRIDGE, NATAL.

While the discovery of diamonds may be said to have inaugurated the first era of the Cape Government railway policy, the discovery of gold on the Rand in 1886 ushered in the second and most important epoch. Immediately the extent of the deposit of the "Golden Fleece" became realised, all efforts were made to connect the Rand with the coast.

Of this railway rush to the Rand an

interesting story may be related. In 1884 the Transvaal Government suggested that the Government of Cape Colony should connect Cape Town with Pretoria, via Fourteen Streams, Klerksdorp and Pot-

posal had received, refused to be cajoled. Now it held the whip-hand. Every port was striving to get into touch with Johannesburg and Pretoria. The Transvaal Government, instead of being the beggar, was



Photograph supplied by the South African Railways.

WHERE RAILWAY BUILDING IS ROUGH AND HARD IN CAPE COLONY.

The track threading the mountains near Ceres.

chefstroom. As relations between the two countries were somewhat strained it is not surprising that the Cape Government turned a cold shoulder towards the proposal, especially as there were very slight evidences of the extension proving profitable.

Two years later gold was found, and one of the wildest rushes on record ensued. The Cape Government, realising the vast traffic that this industry was certain to create, at once desired to get to Johannesburg, but the Transvaal Government, remembering the cavalier treatment its pro-

posal had received, refused to be cajoled. Now it held the whip-hand. Every port was striving to get into touch with Johannesburg and Pretoria. The Transvaal Government, instead of being the beggar, was

now in the position to hand out favours, and it took time to discuss the various propositions so as to secure the best terms for itself. Foiled in its efforts to get through in the manner it desired, the Cape Government made overtures to the Orange Free State. The Cape line had been carried as far as the southern boundary of this neighbour, and the Government now offered to extend the road through the breadth of the Orange Free State to the Vaal River. The Orange Free State, recognising the opportunity to

place its capital (Bloemfontein) in touch with East London, Port Elizabeth and Cape Town, agreed to the proposal. This extension was taken in hand in 1889, and was completed in three years. Upon reaching the Vaal River the authorities of the Cape Government were in danger of being balked once more, but the difficulty was solved by the Netherlands South African Railway undertaking to carry it from the Orange Free State northern boundary to Elandsfontein.

Had the Cape Government accepted the Transvaal's suggestion of 1884, it would have pioneered railway construction in the South African Republic. Owing to the rejection of this proposal, Stephenson's "devil machine" did not get a hold in the Transvaal for some years, when an unpretentious single track was laid to handle traffic upon the gold reef. Considerable prejudice had to be overcome even before this concession was granted, since many of the unsophisticated members of the Volksraad regarded the locomotive as an instrument of his Satanic majesty, and hesitated to father it lest they should encounter wrath untold from the heavens above. But once these pious members were defeated, development went forward with a headlong rush. Yet it was only twenty years ago that Pretoria was linked with the coast by railway, but the conquest was complete, because by 1895 Kruger's stronghold was in direct communication with all the big seaports between Lorenzo Marques and Cape Town.

So far as the original trunk road was concerned, it became relegated somewhat to an inferior position. To travel between Johannesburg and Cape Town involved a somewhat circuitous journey. Going north, the pioneer line was followed as far as De Aar Junction. Then the train doubled back for nearly 100 miles to Naaupoort Junction, to meet the direct northward line via Bloemfontein and Vereeniging. Kim-

To
Pretoria.

The De
Beers
Company.

berley became side-tracked; the railway came to a dead end there, though it was obvious that a line should extend therefrom to the Rand. As the Cape Government was unable to enter the Transvaal from this point, private interests stepped in to fill the gap. The De Beers Company conceived the idea of building a link running north-eastwards from Fourteen Streams to Klerksdorp. It approached the Cape Government, and persuaded the latter to extend its road beyond Kimberley to Fourteen Streams. De Beers went ahead with their project, and at Klerksdorp joined hands with the line running to the Rand. In this way a direct route between Cape Town and Pretoria was provided, while Kimberley was linked with the Gold Centre. The De Beers Company scored in another direction also, since the section which they built gave them a short haul for the coal which was required so urgently at the diamond mines.

Two years later the De Beers Company achieved another smart coup. At that time if one desired to make Bloemfontein from Kimberley, a journey of several hundred miles northwards via Johannesburg, or southwards via Naaupoort Junction and De Aar, was unavoidable, despite the fact that the two points, as the crow flies, are scarcely 100 miles apart. But it remained for the famous mining organisation to span the gap with almost an air line.

Although the Cape Government committed itself to the railway conquest of its country, private enterprise has not by any means been extinguished. In addition to the enterprise of the De Beers Company, another striking illustration of unofficial railway building activity is offered in the southernmost extremity of the country. This is the New Cape Central Railway, a British concern which was founded in the 'eighties to carry an extension from Worcester ultimately to Mossel Bay, and,

The New
Cape
Central.

in conjunction with the Grand Junction Railway, which was to build a line between Port Elizabeth and Mossel Bay, to provide a short cut between Port Elizabeth and Cape Town. The prospects confronting

difficulties. Eventually the Government stepped in and took over the work. It struck out from Mossel Bay and tacked on 33 miles as far as Georg, which it handed over to the British company to operate.

But there still remained a gap of some 30 miles between Georg and Oudtshoorn in order to give the short cut between the two ports. The Government turned some 300 convicts on to the job, but even then failed to make rapid headway. At last the outstanding section was attacked in grim earnest, as the short cut was in urgent request. Nearly a thousand free labourers were brought in, while the number of convicts was increased appreciably. In this way work went forward more rapidly, and now the two ports have been drawn 180 miles nearer together.

While the railway conquest of the Cape was under way an equally aggressive expansion policy was being manifested by Natal. But here the conditions were vastly dissimilar. The



Photograph supplied by the South African Railways.
A DEEP CUTTING AMONG THE MOUNTAINS ON THE CERES LINE.

the enterprise were far from being attractive at the time of its inception, but as the route lay through exceedingly fertile agricultural country, it was maintained that within a few years complete success would be achieved, while, in addition, there was the possibility of building up a flourishing new port at Mossel Bay.

Unfortunately, although the New Cape Central completed its project step by step and reached Mossel Bay in 1906, the other company, coming westwards, got into

country is scarred through and through by broken mountain ridges, the penetration of which taxed the engineers severely. The issue from their point of view was rendered additionally perplexing from the fact that financial stringency demanded the maximum mileage for the minimum expenditure. The problem was not so much a question of how to overcome an obstacle as how to avoid it. Accordingly the engineers introduced stiff banks and sharp curves in abundance.



Photograph supplied by the South African Railways

CONSTRUCTING THE RAILWAY OVER THE OULENIQUE MOUNTAINS BETWEEN
GEORG AND OUDTSHOORN.

Some idea of the task with which the plotters were faced may be conceived from the fact that on the main line out of Durban, over which flows the bulk of the traffic, banks of 1 in 30 and curves of only 300 feet radius prevail.

After buying the six miles forming the system of the Natal Railway Company, the Government decided to link Durban with the capital at Pietermaritzburg with all speed, as well as commencing the north shore line as far as Verulam, and a south shore line to Isipingo, the whole aggregating 98½ miles. Since then the main line has been continued into the interior, the north shore line has been carried as far as Somkele, in Zululand, while the south shore road has been extended from Isipingo to Port Shepstone and Murchison, and from the latter point inland to Harding.

The original permanent way was of the

flimsiest description. Iron rails, weighing 40 pounds per yard, were spiked to sleepers in the American fashion. The iron rails were torn out within a very short time to make way for steel rails weighing 45 pounds per yard. In turn these have been displaced by 80-pound rails on the main and by 60-pound rails on the branch lines.

In driving the line to the capital the engineers had to perform some very stiff work. Owing to the land rising abruptly from the shore a ruling grade against west-bound traffic of 1 in 30 was found to be unavoidable, and this is continued for some 30 miles to Botha's Hill at about 2,300 feet. A slight descent to 2,000 feet is followed by another immediate rise to Thornville Junction at 3,000 feet. Then comes another severe drop of 1,000 feet in 13 miles, giving way to an immediate ascent at 1 in 30 to reach Pietermaritzburg.



Photograph supplied by the South African Railways.

ONE OF THE THREE JETTIES AT PORT ELIZABETH, ALGOA BAY.



TRANSPORTING A STATIONARY STEAM ENGINE ACROSS A RIVER IN SURINAM.

Transporting Freight Through the Air

SOME REMARKABLE AERIAL RAILWAYS IN VARIOUS PARTS OF THE WORLD



DURING the past few years the utilisation of the air as a channel of transportation has undergone considerable development. In mountainous countries, where the population is sparse or scattered, and where the topographical conditions are certain to render a locomotive line a costly matter, no system is so economical, either in initial outlay or maintenance, especially in the movement of freight, as the aerial railway.

There are several works of this character scattered throughout the world which have served to solve complex economic problems to a unique degree. In Spitzbergen the

aerial railway offers means of getting glacial coal from the adits to vessels; in China it links remote coal-bearing districts with strategical shipping points; in the Andes it connects rich mineral deposits buried in the heart of the loftiest peaks with the country's locomotive railway system, and so on.

Some two or three years ago the Prometna Bank, one of the largest commercial and industrial undertakings in Belgrade, secured the right to exploit some of the richest timber reserves in Servia. The district taken over was that lying on the Zlatibor plateau, between the Drina River and Bosnia. This tract of country is exceed-



TYPICAL WOODEN TOWER SUPPORTING THE
SERVIAN LUMBER AERIAL RAILWAY.

ingly rugged, many of the peaks rising to 5,000 feet or more, while the slopes of the mountains, which are somewhat precipitous, are broken freely by steep deep ravines. The low-lying parts of the highlands are thickly clothed with beech, but the wood, owing to the prevailing moist conditions, is too soft to be of much commercial worth. On the other hand, the timber found on the higher reaches, where a drier climate is experienced, is of distinct marketable value.

Logging methods which are practised in other parts of the world were tried here, but, owing to the physical conditions, were not particularly successful, through the difficulty of making gravity slides, and the

limited character of the waterways for floating the logs down to the mills. Accordingly the concessionaires, in their search for a superior method of transporting the lumber, approached the Bleichert Aerial Transportation Company of London to ascertain if aerial methods were practical. This organisation dispatched its surveyors to the Balkans to scour the afforested country, and to discover a practical route for an aerial line which would meet the requisitions.

The surveyors scaled the peaks and threaded their way laboriously over the densely wooded scarred slopes. After diligent search the plotters finally discovered a feasible alignment from a point on the Drina River near the Derventa Valley, down through a part of the latter depression, and then in a bee-line to another point known as Predov-Krst, where the loading station was to be established.

Although this line is only four miles in length, it attracts attention owing to its daring character. Within this distance a difference of 2,600 feet in altitude is overcome. Again, in order to secure the required alignment two tunnels had to be driven through projecting crags which stood in the way of a direct road to the loading station.

Owing to the line traversing the most broken country among the mountains, its erection was attended with considerable difficulty. After reaching the station on the Drina, it continues its way from the left to the right bank of the Derventa Valley with a free span of 2,600 feet. Completing the leap, it reaches one of two mountain crests which project forward to such a degree that to have avoided them in the location would have been to incur greater difficulties. Therefore the engineers, finding just sufficient room for a support on the first crest, seized it, and then drove a tunnel through the second projection for a distance of

about 170 feet. This tunnel was set in a particularly trying position, the wall being sheer. As a result the workmen engaged in boring found no natural footing whence they could force their way, so had to be slung over from the crest by means of ropes, plying their tools from crazy swinging platforms as best they could.

Emerging from the tunnel the line makes another daring spring, some 1,300 feet in length, to enter the second tunnel, which likewise is driven through a precipitous tooth of rock for 85 feet. Thence it makes another leap in a free span of 1,300 feet to reach the unloading station.

The surveyors, clambering among the crags with their transits and levels, had many thrilling adventures. Frequently they had to be lowered over nerve-racking precipices, manipulating their instruments and taking their readings under very precarious conditions. The natives also occasioned considerable trouble. As the plotters advanced they marked the path of the line in the usual manner with pegs. Some of the inhabitants, ignorant of the significance of these unpretentious marks, pulled them up for their own use, while others, animated by more sinister motives, purposely moved them in order to misguide the engineers. Consequently, when the surveyors made a final run over their location in order to revise it if at all possible, they often had to indulge in wild-goose chases after the pegs, or were compelled to carry out considerable unnecessary work owing to having been misled. All the material utilised in construction had to be conveyed from Belgrade to the site by sledge or lorry over

rough, unmade roads, and when these were non-existent or impracticable, owing to the steepness of the slopes, had to be carried by porters. In making the excavations for the pier foundations the builders experienced considerable trouble through the unsatisfactory character of the ground.

Owing to the extreme fall in the line no power whatever is required for the drive; on the contrary the excess power which is developed has to be absorbed by braking, since otherwise the descending loads would attain far too high a velocity. The hourly carrying capacity of the railway is 885



THE ENTRANCE TO THE TUNNEL ON THE SERVIAN LUMBER RAILWAY THROUGH WHICH THE AERIAL-WAY IS CARRIED TO OVERCOME A MOUNTAIN SPUR.

cubic feet, or 18 tons, in trunk lengths of 4 to 50 feet of timber. At a travelling speed of $6\frac{1}{2}$ feet per second for the traction rope, the carriers follow one another at more or less regular intervals of 1,300 to 1,650 feet. The well-known Bleichert "Automat" system is employed, and the

this form of transportation, carried out some very notable works at Bilbao, while during recent years the Bleichert Transportation Company has completed many striking installations. One of these brings down ore from the lofty reaches of the Canigou, the King of the East Pyrenees,



THE UNLOADING STATION OF THE SERVIAN LUMBER AERIAL RAILWAY UPON THE DRINA RIVER.
The logs are made up into rafts and floated down the waterway.

special locked steel carrying ropes have a diameter of $1\frac{9}{16}$ inch and $1\frac{5}{16}$ inch respectively, while the traction rope is $\frac{2}{3}\frac{1}{2}$ inch in thickness.

Owing to the mountainous nature of the Pyrenees the aerial railway has been extensively adopted, because it offers a cheaper solution of the transportation problem than the adhesion surface line. In the transportation of ore it has proved strikingly successful. Some years ago the English firm of Bullivant and Company, who probably were among the pioneers in

whose crest is wrapped eternally in snow. The deposits are tapped at an altitude of 4,500 feet.

The line comprises two sections of aerial ways with an intervening length of locomotive line $8\frac{3}{4}$ miles in length. The first stretch of aerial way is about 4,200 feet in length, while the second section is about 2.8 miles long, terminating at Amélie.

On the upper section of the line, although there is a relatively slight fall rendering automatic working possible, an excess of 10 horse-power has to be absorbed by a hand-



THE GREAT SPAN OF 2,600 FEET ON THE SERVIAN LUMBER AERIAL RAILWAY.
The line springs from cliff to cliff across the Derventa Valley.

controlled band brake. But on the second aerial section the descent is nearly 3,000 feet, and as with an hourly capacity of 50 tons an excess of more than 100 horsepower is developed, hydraulic brake governors are installed to absorb this superfluous energy.

The cableway is called upon to span some formidable ravines. The longest span is on the uppermost section across a deep valley 1,700 feet in width. Deep in the valley below is the hydro-electric plant where the current for light and power at the mines is generated.

The cableway also offers at times a simple

and successful means of overcoming what otherwise appears to be an insuperable difficulty. One of the Bleichert engineers, when at work in Surinam, was balked by a swiftly flowing river 1,000 feet in width, over which it became necessary to transport a portable engine. As there were no bridges or boats available, and the suggestion of a raft not meeting with approval, he conceived a novel and bold idea. He ran up a tower on each bank, between the tops of which he stretched a cable. He then fashioned a sling, similar to those employed for handling motor-cars on the Channel

steamers, on which he set the steam engine, chocking it firmly in position. This load he suspended from a Bleichert carrier, hoisted it into the air, and pulled it along the ropeway to the opposite bank. At first sight this may appear to be a somewhat expensive proceeding, but in reality the task was achieved for only about £100. Furthermore it provided him with an efficient and simple means of transporting across the waterway all other material which was required for constructional purposes.

But possibly one of the most comprehensive and interesting aerial railway installations which ever has been undertaken is that which was laid down for the shipment of nickel ore from the mines of New Caledonia. The conditions here were somewhat different from those which generally have to be fulfilled. The port is deficient in shipping facilities, and, consequently, vessels calling for cargoes were forced to lay about three-quarters of a mile off the shore, the freight being brought out in small boats, which had to run the gauntlet of the heavy surf.



LOADING THE LOGS ON THE SERBIAN LUMBER AERIAL RAILWAY,

The physical characteristics of the island were also somewhat adverse to the adoption of the usual forms of transportation. The country rises abruptly from the beach, so that the laying of a surface road would have entailed a big outlay as well as being of considerable length in order to maintain working grades and curves. There was another factor which had to be taken into consideration. Nickel is found and exploited upon adjacent islands, is brought to the central shipping point in small craft, and there transferred to the stock depots to await the coming of an ocean-going vessel. This entailed transshipping.

Accordingly the mining concessionaires sought for a means of overcoming all the various disadvantages in one stroke, and the engineers of the company who planned the lumber line for the Servian Prometna Bank were invited to visit the South Seas to become familiar with the peculiar situation on the spot. As a result of their reconnaissance they elaborated a very comprehensive plan. This was the erection of an island loading pier in the bay, some 3,300 feet from the shore, fitted with the latest appliances for handling ore, coal, and ballast in bulk expeditiously, and provided with ample hoppers for storage purposes. They also suggested that the transportation of the ore from the mines to the dumps by the water's edge, as well as connection between the shore and the landing stage, should be carried out by an aerial railway, the line being at a sufficient height above the water to escape the waves.



A SPAN OF 1,700 FEET ACROSS A RAVINE IN THE PYRENEES.

The project met with approval, inasmuch as it solved the question completely. The landing stage offered berthing accommodation in deep water for the largest vessels frequenting the port, and by lying alongside the hoppers the boats could take on a full cargo of ore in the minimum of time. Also coal brought in for the mines could be unloaded and dispatched readily to shore, while ballast could be removed with equal expedition. Small vessels coming in with cargoes of nickel from the neighbouring islands can be discharged similarly, the consignments either being emptied into the stage hoppers or transferred to the shore stock-dump. Passengers also can be handled by the railway, thereby avoiding the hazardous run through the surf.

The aerial railway was accepted for another reason. It offered a simple and inexpensive means of building ore dumps, since it was intended to create and maintain stocks of 50,000 tons on shore, which meant the creation of a huge pile some 65 feet in height.

Owing to the involved and multifarious duties which had to be performed by the aerial railway, an apparently intricate system has been laid out. It comprises four distinct lines. The network consists of some 8,300 feet of track, of which the longest section is that connecting the shore with the island loading and unloading stage. But all traction ropes are put in motion from a single central station. With the exception of one line, upon which a capacity of 40 tons per hour is adequate, all the lines have a capacity of 100 tons per hour, including the sea-going line over which passenger and ore traffic, coaling and watering of vessels, is maintained.

The landing stage has a total length of

about 235 feet, and is fitted with the latest time- and labour-saving appliances for the work it is designed to fulfil. In order to maintain the working speed of the line the track upon the landing stage is provided with several short sidings and switches, on which the trucks can be turned upon arrival, while when emptied they are run out again on to the main line, swung round the loop at the end of the stage, and sent on their return journey to shore.

This plant, which constitutes one of the most complete and remarkable in the southern hemisphere, has wrought vast changes. Whereas formerly a 3,000-ton vessel could not load up under 20 days, and generally was detained for 40 to 60 days to take on its cargo, the period of detention now is never more than three days. The saving in labour is just as striking. Formerly several hundred natives had to be engaged to work the barges; now a few dozen hands are adequate to run the aerial-way and the stage as well.



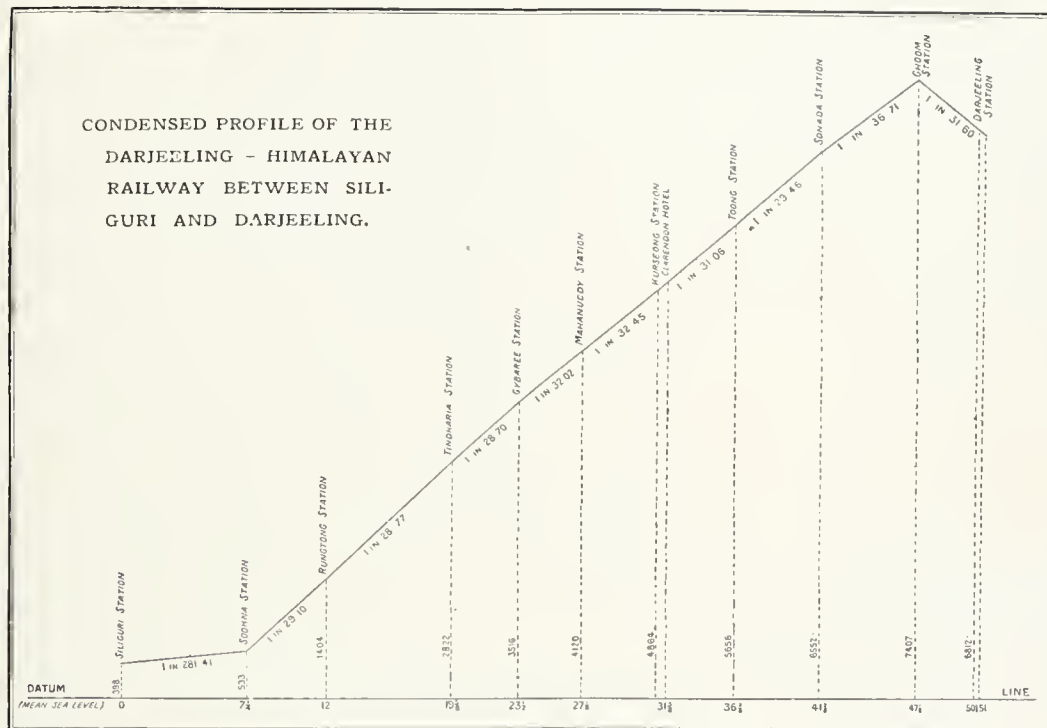
THE NICKEL ORE AERIAL RAILWAY IN NEW CALEDONIA.

The line spans the sea for 3,300 feet to connect the island landing stage with the shore



TRAIN ROUNDING "AGONY POINT," THE SENSATIONAL LOOP ON THE DARJEELING-HIMALAYA LINE, THE MOST REMARKABLE MOUNTAIN RAILWAY IN THE WORLD.

CONDENSED PROFILE OF THE
DARJEELING - HIMALAYAN
RAILWAY BETWEEN SILI-
GURI AND DARJEELING.



The Most Remarkable Mountain Railway

EXTRAORDINARY FEATS OF ENGINEERING EXHIBITED ON THE DARJEELING-
HIMALAYAN RAILWAY IN INDIA



ONLY those who are compelled to spend the whole year round upon the Plains of Bengal are able to appreciate that the sizzling lowlands recall "Hades with the lid on." Consequently it is not surprising that Europeans endeavour to escape during the Indian summer to a spot where the white man is able to breathe, despite the fact that it involves a climb of 7,100 feet.

For this reason the little railway, 54½ miles in length, which winds to the heights of Darjeeling is as heaven-sent balm. Before it came the journey from Calcutta

to the temperate climes above was not to be undertaken lightly. Some five or six days were required to cover the 329 miles to Siliguri, whence a first-class road, built by the Government at a cost of £6,000 per mile, meandered upwards towards Darjeeling, 7,500 feet above sea level.

The railway follows approximately the same route. The money for this enterprise was subscribed almost entirely in India, and the Government, never favourably disposed towards private enterprises in the railway field, only extended two concessions worthy of remark. One was the guarantee that the gross receipts should never fall below

a certain figure; the other that it would for all time maintain the cart-road.

Siliguri, some 400 feet above sea level, was selected as the lower terminus, and as the track was to be lifted 7,100 feet in some 50 miles, heavy grades and sharp curves were unavoidable—the surveyors plotted banks ranging from 1 in 19 to 1 in 36.71 and curves of 50 feet radius.

A gauge of 2 feet was selected. Also it was decided to work the line wholly by adhesion, despite the fact that train-loads would be somewhat restricted. Thereby it may seem a “toy railway,” but it is substantially constructed, steel rails weighing $41\frac{1}{4}$ pounds per yard being laid on wooden sleepers.

Construction was commenced out of Siliguri in 1879. For the first 7 miles the

**How the Line
was Built.**

going was comparatively easy, the ascent being only 1 in 281.41 to Sookna station. The heaviest piece of work upon this section was the erection of the steel bridge, 700 feet in length, comprising seven 100-foot spans, across the Mahanuddy River. Leaving Sookna, mountain climbing commences in grim earnest, because 871 feet in altitude have to be overcome in $4\frac{3}{4}$ miles. Four-and-a-half miles out of Sookna the builders were confronted with the first serious piece of development work. The ascent was so sudden that a spiral was unavoidable, the track describing a sharp loop through a deep cutting to gain the higher level. Some four years later the mountain-side slipped into the cutting, completely filling it. As the idea of re-aligning this section, in order to reduce the grade, had been discussed, the blocking of the road presented the opportunity to undertake the new work.

After leaving Rungtong station at 1,404 feet altitude, the average grade stiffens to 1 in 28.77 for the next $7\frac{5}{8}$ miles in order to gain Tindharia station at 2,822 feet. Shortly after passing the thirteenth mile-post the railway enters upon one of the

most complicated and interesting pieces of development work upon the road. This is practically a double loop to overcome a sudden rise of 137 feet. The lay-out of the line at this point may be understood by referring to the diagram (page 625), the outstanding feature being the sharp curvature introduced to fit the alignment to the situation.

Before Tindharia is gained further ingenuity of a different character had to be exercised. A spiral being impracticable owing to the lay of the mountain, a reverse was adopted. At 2,438 feet the line climbing at 1 in 28 enters a curve of 800 feet radius, giving way to one of 400 feet radius to reach a dead-end at 2,473 $\frac{1}{2}$ feet. It then backs up a second leg rising at 1 in 33 round curves of 400 and 200 feet radius respectively to a second dead end at 2,501.15 feet. Another climb at 1 in 28 round a curve of 400 feet radius brings the metals to 2,536.5 feet, so that by means of this reverse or zig-zag 97 $\frac{1}{2}$ feet vertical lift are negotiated.

In the $3\frac{3}{8}$ miles between Tindharia and Gybaree stations the heaviest average gradient of the line is encountered —1 in 28.70. A zig-zag outside “Agony Point,” the first-named station gives the railway its first decisive lift, and then comes the fourth and final spiral on the railway. This is generally regarded by the traveller as the most sensational spot of the road, and has become familiarly known as “Agony Point.” It represents the ascent of another of those conical spurs which are so common in this locality, but in this case there was such a tight squeeze for space that on the upper part of the loop a curve of 59 $\frac{1}{2}$ feet radius had to be described. The train virtually overhangs the hillside at this point.

Emerging from this spiral the line shortly afterwards makes another see-saw up the mountain side in order to enter Gybaree station, while at the twenty-fourth mile-post the last of these switchbacks is

negotiated, the grade becoming slightly easier—1 in 32·02—for the succeeding 4 miles to Mahanuddy at 4,120 feet above sea-level.

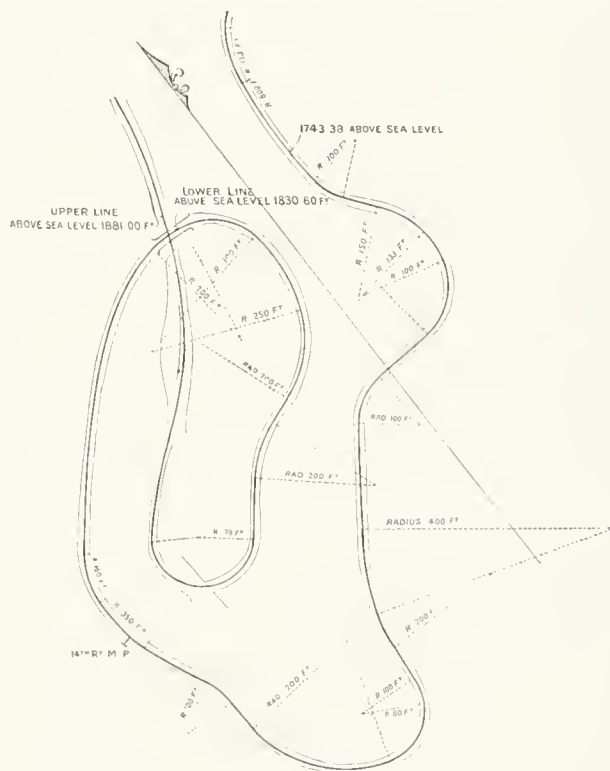
Passing the twenty-fifth mile-post the railway enters what has become recognised as the most troublesome piece of track throughout its length. The rainfall in this locality is terrific, with the inevitable result—landslips and rock-slides are of frequent occurrence, and occasionally are extremely devastating. Scarcely a season passes without some damage to the permanent way, but the worst misadventure was that which was experienced in July, 1890. There was an abnormal downpour, 14 inches of rain falling in six hours! Naturally the railroad felt the brunt of it. So much so that 800 feet of line were torn up and the grade washed out of recognition.

The upper levels of the line are somewhat free from striking examples of engineering beyond deep cuts and heavy side-hill excavation. Leaving Kurseong the grade stiffens slightly to 1 in 31·06 for about 5 miles to Toong, followed by a sharper rise at 1 in 29·46 for 5 miles to Sonada. Then comes the easiest stretch upon the whole mountain section, although it is 1 in 36·71, in order to reach the summit at Ghoom, 7,407 feet above the sea. Immediately the line commences a descent upon a ruling grade of 1 in 31·60 for nearly 4 miles to Darjeeling station at an altitude of 6,812 feet. On this final section, however, the steepest piece of grade on the line is found, the bank ranging from 1 in 22½ to 1 in 23 for some three-quarters of a mile.

The panorama unfolded from Darjeeling is one of unparalleled grandeur. The northern horizon is the eternally white rampart formed by the Himalayas—the white roof of the world—which through the clear atmosphere appear barely 50

miles distant. The two loftiest peaks known, Mount Everest (29,000 feet) and Kinchinjinga (28,500 feet), are plainly discernible.

As may be imagined, upon such a railway, abounding in steep banks and sharp curves, the train itself is a point of intense interest. It is Liliputian in the true sense of the



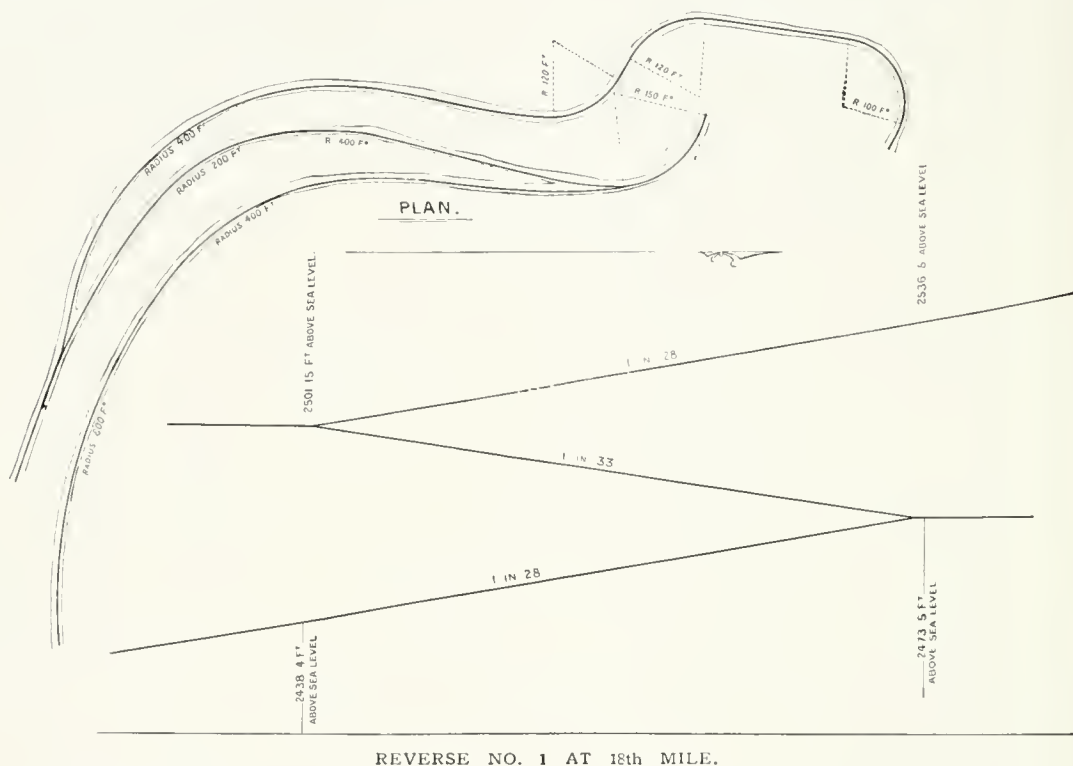
LOOP NO. 2 AT 14th MILE. GRADIENT 1 IN 28.

word. When first opened engines weighing about 8 tons, and capable of hauling a load of 10 tons behind them up the maximum grades of 1 in 19 and round the sharpest curves of 50 feet radius, were used. In order to secure an easier ascent, and to enable the engine to haul a greater paying load, the banks were reduced, the steepest average rise now, as already mentioned, being 1 in 28·70, while the curves were opened out to a minimum of 69½ feet, though on one or two of the loops, owing to lack of elbow-room, some of 60 feet radius still remain. By carrying out these improvements it became possible to employ larger and more powerful locomotives weighing 12 tons, and

capable of hauling 27 tons behind them up grades of 1 in 25. A larger locomotive weighing 14 tons, and able to handle 50 tons up a similar bank, is now in use, as well as the Garratt engine mentioned elsewhere.

The rolling stock is likewise of diminutive proportions. The first class carriages are

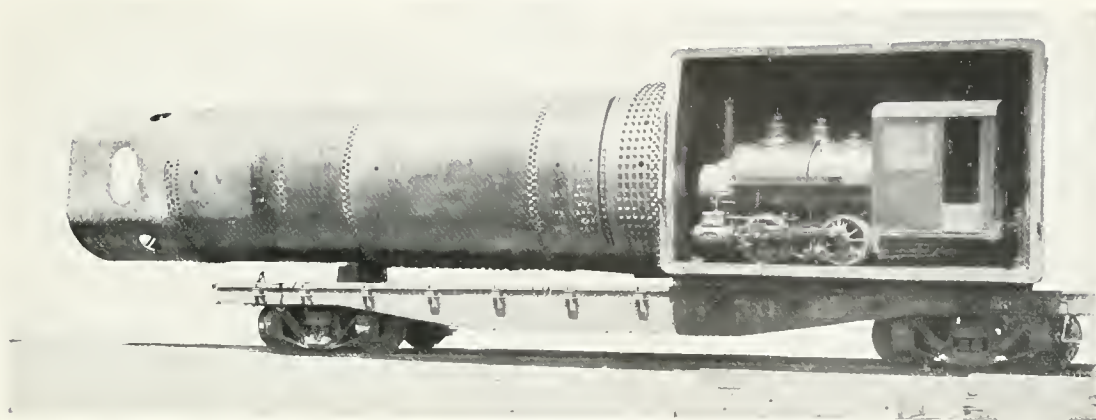
Travelling on this railway has not been without humorous incident. After leaving Sookna station the train traverses a dense jungle where wild elephants abound. One day, when the 8-ton locomotives were in service, the driver was perturbed by the sight of a herd of these creatures imme-



13 feet in length by 6 feet in width, and $7\frac{1}{2}$ feet from rail level to roof. They are fitted with $19\frac{1}{2}$ inch wheels, and the floor is set very low. They are divided into two compartments, and have accommodation for twelve passengers, with space for packages. In addition there are open trollies with fitted hoods and curtains for protection against inclement weather. Baggage and merchandise are carried in covered trucks, so that the Darjeeling "mail" is a somewhat curious combination of vehicles. The maximum speeds are 12 and 9 miles per hour on the up and down journeys respectively. The climb occupies about seven hours, including an hour's stop at Kurseong for tiffin.

diately ahead. The engine was puffing laboriously on the heavy grade, and the driver tooted his whistle freely in the hope of scaring the pachyderms. But one wicked old tusker wheeled round, planted his feet firmly in the 2-foot way, glared fixedly at the oncoming train, and trumpeted wildly. The driver did not hesitate. He reversed his engine instantly, and backed into Sookna station as fast as he could, leaving the elephants in undisputed possession.

The passenger business of the line is heavy and lucrative, but the mainstay is the tea transport, the gardens which clothe the mountain sides for miles around Darjeeling producing over 10,000,000 pounds per annum.



THE HUGE BOILER OF THE VIRGINIAN MALLET LOCOMOTIVE.
The fire-box is large enough to hold the works' shunting engine of the builders.

The Most Powerful Mallet Freight Locomotive

A 2-8-8-2 COMPOUND ENGINE WHICH WEIGHS, EXCLUSIVE OF THE TENDER,
241 TONS



WHEN the Virginian Railway was built, the fathers of the enterprise realised the salient fact that the greater the tonnage of coal which they could move per train from the collieries to the coast, the higher would be the ton-mile revenue. Although the line is laid out in accordance with the very latest ideas concerning railway construction, with grades kept down and curves well opened, it was physically impossible to avoid one or two stiff banks, notably upon what is known as the Deepwater Division, comprising a distance of 14 miles between Elmore and Clark's Gay, whereof $11\frac{1}{2}$ miles have a ruling grade of 1 in 48.

In drawing up the train-operating arrangements the authorities decided that the very utmost which the huge freight engines could haul over the greater part

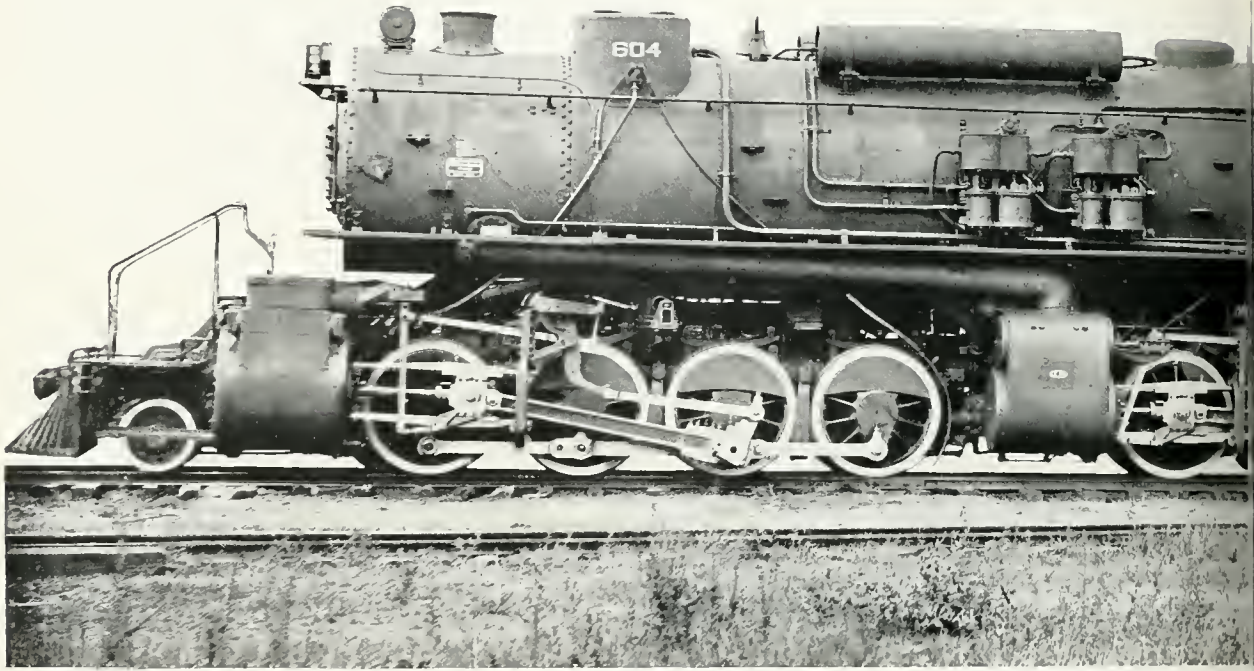
of the line should be put over this bank intact, but that no more than three locomotives should be attached to the train for this purpose. The powerful Mikados, with from 103 to 120 (American) tons on the drivers, could handle a train comprising 80 loaded 50-ton ears under double-heading practice with ease upon the ordinary sections of the roads; but the climb through the Deepwater section, that became the key to the whole issue.

Accordingly, when the railway was opened, a fleet of four Mallets, of the 2-6-6-0 type, with 150 and 240 tons on the drivers, were built by the American Locomotive Company to serve as pushers. They were huge machines of their day, having a maximum tractive effort of 70,800 pounds. The Mikado road engines were kept at the head of the train, and a Mallet assisted them over the bank. The success attending this method of operation

may be gathered from the fact that on one occasion a train of 120 cars, each of 50 tons carrying capacity, 5,340 feet in length—60 feet in excess of a mile—and weighing no less than 9,140 tons exclusive of the locomotives and brake van, was run from the collieries to the seaboard.

Owing to the success of the first batch

Locomotive Company the authority to design and build the largest and most powerful engine of this type which has yet emerged from the shops of this constructional organisation. It is a mammoth in very truth, because the engine alone measures no less than 66 feet in length by 16½ feet in height, and weighs 241 tons.



THE HUGE MALLET 2-8-8-2 COMPOUND LOCOMOTIVE, USED

It weighs 347 tons complete in running order.

of Mallets a further instalment of eight machines was acquired. These locomotives were still more powerful, though of the same wheel classification, the tractive effort being 92,000 pounds. When these latter were brought into service, the former Mallets which had done duty as pushers were placed at the head of the train, thereby displacing the Mikados. At a subsequent date a still larger and more powerful machine of the 2-8-8-2 classification, and having a tractive power of 102,000 pounds, were built, and in turn took over the pusher service.

The success of these latter Mallets prompted the railway authorities to go still better, so they gave the American

The engine is of the 2-8-8-2 compound type, the forward engine carrying the low-pressure and the rear engine the high-pressure cylinders. The former have a diameter of 44 inches, while the diameter of the latter is 28 inches, and the stroke is 32 inches. At the front end the diameter of the boiler, outside, is 100 inches, while that of the largest ring is 112 inches. The over-all length of the boiler is 50 feet 1½ inches. It carries 334 tubes, each 24 feet in length by 2¼ inches diameter, the heating surface of which is 6,462 square feet. The fire-box measures 11 feet in length by 9 feet wide, and some idea of this enormous size may be gathered from the fact that it is sufficiently spacious to

accommodate the "Dinky" yard engine with ease. The heating surface of the fire-box is 380 square feet, bringing the total heating surface up to 6,842 square feet, while there are 1,310 square feet of super-heating surface. The grate area is 99.2 square feet. Steam is used at a pressure of 200 pounds per square inch.

tons of coal, representing in running condition a total weight of 106 tons.

This enormous locomotive develops a tractive effort of 115,000 pounds when working compound, and 138,000 pounds under simple conditions of operation. It is used in the pusher service, the locomotives which it has displaced, and which



IN THE COAL SERVICE OF THE VIRGINIAN RAILWAY.
It has been built for "pusher" service.

The driving wheel base is 15 feet 6 inches by 15 feet 6 inches, the total wheel base of the engine being 57 feet 4 inches, while that of the engine and tender is 91 feet 5 $\frac{1}{16}$ inches. The driving wheels are 56 inches in diameter, and the weight on the eight pairs of driving axles is 237 $\frac{1}{2}$ tons.

In the construction of the parts which are subjected to great strains, such as the engine frames, crossheads, driving wheel tires, main driving axles, and crank pins, vanadium steel has been used freely, while vanadium has also entered into the composition of the cast-iron used for the cylinders and chamber bushes. The eight-wheel tender—two four-wheeled bogies—carries 212 (U.S.) gallons of water and 15

were huge Mallets of their day, being turned into road engines. The general arrangement of working over the 14 miles' hill, where a rise of some 1,330 feet has to be overcome, is to attach one of the 2-6-6-0 engines developing 92,000 pounds tractive power at the head of the train, and two of these monsters at the rear, representing a maximum total tractive effort of 368,000 pounds. By this collection of steam energy it is possible to move a train carrying 4,230 tons of coal over the hill.

The American Locomotive Company has built a considerable number of huge locomotives of the articulated Mallet type, but this represents its greatest achievement in this direction.



THE MASSIVE STEEL BRIDGE WHICH CARRIES THE CHICAGO, MILWAUKEE AND PUGET SOUND RAILWAY ACROSS THE COLUMBIA RIVER, NEAR BEVERLY, WASHINGTON.

It is 2,740½ feet in length.

Building a Transcontinental Railway in Record Time—I

THE STORY OF THE CHICAGO, MILWAUKEE AND PUGET SOUND RAILWAY,
ITS LOW GRADES AND MARVELS OF ENGINEERING



WHEN the steel ribbon, following the western flow of settlement from Chicago, was unwound in the direction of the mighty Mississippi River, the inhabitants of the newly founded communities of the intervening States welcomed it with open arms. This form of transportation was sorely needed to carry the products of the land swiftly and directly to the markets of the consumers. Every temptation to railway expansion was held out, and the speculative element, well to the fore, arose to the occasion with avidity. Railways grew like mushrooms, and were built with feverish haste, so that within a short while the agrarian States

adjacent to the Great Lakes were being criss-crossed in all directions by the grid-iron of steel.

The plungers chuckled: they were on velvet; never had such opportunities to wax rich out of railways been presented. But they received a rude awakening. Once the lines were laid, the States turned round in a vividly savage manner, because they knew that the rails could not be torn up. The railway was a necessity to the community, but that was no reason why the industrious and hard-working tillers of the soil should build up railway millionaires. So they embarked upon a policy of "soaking" the railways: bleeding them right and left in rates and taxes. The result was

that speculators got seared, backed out of their commitments, or collapsed: some lines unable to withstand the unexpected strain sought escape in bankruptcy, to be bought up by more wealthy concerns at scrap-heap prices. The outcome of this devastating policy was the momentous legal decision that each State should possess the right to control the railways within its boundaries, irrespective of the Federal Government, and, in fact, it laid the foundation of the "anti" agitation which is so powerful to-day. Once this decision became known, railway pioneering in that vast country fell into desuetude, except in the extreme west, where the grand old Canadian railway builder, "Jim" Hill, has always been able to get his own way, and to please the powers that be at one and the same time.

Among these roads which crept out of Chicago through the farming country to the Mississippi, although by a somewhat devious route, was the Minnesota Central Railway. It was commenced in 1865, and two years later had reached St. Paul. Subsequently it was purchased by another concern known as the Milwaukee and St. Paul Company, which in the year 1874 changed its name to the Chicago, Milwaukee and St. Paul Railway, by which it is known to-day. This concern survived the first wave of hostility against privately owned railways, and with striking enterprise and energy threw out its tentacles in all directions between the Great Lakes and the Missouri, until, in 1906, its system aggregated some 7,000 miles of line.

Such a network, serving the great agricultural country, suffered under one serious disability. Local timber being unknown, every piece of wood, whether required for sleepers, fencing-posts, flooring, or what not, had to be purchased in distant markets and hauled immense distances over rival roads. The money expended under the item of freight in this direction every year became enormous. Besides, the system was

isolated. The remarkable advance of the western seaboard, and the creation of a rich Pacific maritime trade, did not benefit it one iota. Rather, it suffered, because through Western traffic booked to or from Chicago had to be handed over to or taken from a rival at the outposts of the system. As the transcontinentals had the longer haul, they drew the greater proportion of the revenue accruing from through business.

These two factors impressed President Earling, who held the reins of the Chicago, Milwaukee and St. Paul Railway. The traffic figures were analysed minutely, and two points stood out very assertively. These impressed him, and accordingly, one year he started off upon a long trip westwards. The object of the journey was unknown, but it was generally assumed that the President was taking a long, well-earned vacation. As a matter of fact, he was on more serious and colossal business than he had attempted previously. He ran through the country leisurely, and by keeping well away from the beaten track learned more of his homeland than ever he knew before.

Upon his return to Chicago his friends congratulated him upon the benefits his holiday had wrought. The deep-set tan of his face betrayed that he had braved the open air considerably, while his figure, more tightly knit than ever, proved abundantly that he had not led a lazy holiday. He was enthusiastic over the excellent fishing and general sport which he had enjoyed, but even his most intimate friends could not quite fathom where he had been to secure such a perfect rejuvenation and recuperation of energy.

In the seclusion of his office the President became engrossed in the study of a curious rough map which he had prepared. It was a crude itinerary of his journey, and was covered with variously coloured patches: some green, others blue, brown, black, orange, and so forth. No one but the Presi-

**The
Minnesota
Central.**

**The
President's
"Holiday."**

dent himself and his trusted first lieutenants would have understood this map, even if they had seen it, but it was evident from the inscrutable figures and calculations inscribed upon each coloured patch, that it was of far-reaching significance.

the import of the coloured map were revealed. The first proved that the man at the helm had been spying out the country at first hand, and had discovered the approximate route which the long arm to the Pacific should follow. The coloured



THE SECOND CROSSING OF THE MISSOURI RIVER, AT LOMBARD, MONTANA.

By the waterway the distance from the first crossing of the Missouri at Mobridge to Lombard is 1,000 miles: by the Chicago, Milwaukee and Puget Sound Railway it is 623 miles.

Suddenly, one day, the newspapers blazed out the news that a new transeontinental railway was to be laid across the United States: that Chicago would have another outlet to the Pacific; that Puget Sound would receive another huge boost forward; and that the Chicago, Milwaukee and St. Paul Railway was to back the enterprise.

Instantly the purport of President Earling's prolonged vacation in the west and

map indicated the economic value of the country contiguous to the proposed line, and its respective possibilities in agricultural, mining, industrial, lumbering, and other activities, according to the colours of the patches.

The scheme demonstrated two important facts. In the first place, the 7,000 miles of prosperous prairie lines would be able to take care of the whole of the traffic to and from the Pacific seaboard, while also

it would be in a position to bring in all the lumber required for the parent system. It was found that the saving under this item alone would be sufficient to defray a considerable proportion of the interest upon the capital required for the new line, the cost of which was set down at approximately £20,000,000.

The necessary preliminaries were completed without any loss of time, and the requisite financial backing forthcoming, constructional work was commenced in 1906. Curiously enough, a start was made from the same river in the east for the latest American transcontinental as that which had been selected for the first steel highway across the continent—the east bank of the Missouri River. Also, as in the last-named undertaking, the first step was the erection of a massive steel bridge to gain the opposite shore. The jumping-off point was Mobridge—a contraction of Missouri Bridge—to which point the parent system had reached out, and which was excellently adapted for the purpose, seeing that it formed the natural gateway to the rich

agricultural States beyond. At the same time the earth was turned at the Pacific end at Seattle, as it was decided to carry out the work from both ends simultaneously.



LOOKING ALONG THE LINE FROM ONE OF THE TUNNELS IN SIXTEEN-MILE CANYON, MONTANA.

The crossing of the Missouri River is imposing, the steel structure carrying the metals of this line, which cost £400,000 to complete, being the heaviest yet thrown across this waterway. It comprises three main through truss pin-connected spans, each 420 feet in length, the maximum

height of the steel being 65 feet. The rails are $65\frac{1}{2}$ feet above low water, while there is a headway of 50 feet. The spans are supported on massive stone masonry and concrete piers. Owing to the sharp slope of the banks, an extensive timber trestle approach had to be provided on each side, that on the west shore being about 2,900 feet long, followed by three plate girder spans. The timber trestling, however, was purely temporary, as it was to be filled in at a later date to form embankments.

Before this bridge was taken in hand an important piece of preliminary work had to be accomplished. On the west bank the location traversed the mouth of the Grand River, which empties into the Missouri at this point. Accordingly, the engineers set to work to divert this tributary from above the bridge and to provide it with a new outlet into the main waterway below the structure. The old channel then was filled in. This work contributed to the long trestle approach to the bridge on this shore as it cuts directly across the reclaimed area.

Leaving the river, the line strikes north-westwards, an easy pathway being found for 45 miles up the Oak Creek Valley. Then it bears almost due west, hugging the boundary line between North and South Dakota, heading towards the Little Missouri River, which is picked up at Marmath, a new town which has been born of the railway. Between the two Missouris the railway traverses some of the most historically interesting country on the plains—the Standing Rock Reservation, now the home of the Sioux Indians. The Americans have good reason to remember this doughty tribe, for it proved one of the most difficult to subdue. Here may be seen the grave of the untamed “Medicine Chief,” Sitting Bull, with that of his inseparable companion and ally, Rain-in-the-Face, alongside. The peaceful occupation and industry of the survivors of this once great tribe contrasts vividly with the stirring times that were

**The Indian
Reservation.**

**The Haunt
of the
Buffalo**

encountered when the first transcontinental was driven across this country

Owing to the gently rolling character of the prairie, rapid progress in construction was recorded, and little difficulty of a technical character was encountered, although for the first 176 miles, owing to the gradual inclination of the plains towards the Rocky Mountains, there is a continuous slight ascent. Near Marmath the line runs for a short distance through the “Bad Lands,” threading the weird, massive, sun-baked formations of clay, which are of no value whatever except to offer shelter to cattle and to present wonderful colour effects under different conditions of sunlight, which serves to emphasise more or less this or that coloured stratum of rock and clay, causing it to assume every tint in the rainbow. In approaching Marmath there is a slight downward run for 14 miles, but immediately the waterway is crossed another uphill pull follows for 16 miles to Kingmont, in Montana, through the country made memorable by the desperate struggle for supremacy between Custer and his implacable foes, the Sioux.

At Terry, on the Yellowstone River, the new transcontinental crosses its rival, the Northern Pacific, so as to pick up the Musselshell River. Leaving Terry, the line has an ascending grade for 134 miles to Sumatra, followed by a downhill run for 16 miles, when occurs the long uphill pull through the Musselshell Valley to Summit, a matter of 151 miles. The Musselshell Valley is one of the most fertile depressions in Montana, the soil being a deep, rich volcanic ash. Since the railway came this depression has been filled up and developed rapidly. In the distant past the buffalo, in its migration alternately north and south in search of pasturage, cut across this river, the trail rammed down by the millions of feet still being plainly discernible, although subsequently it became the stage-coach road. The most important centre in the valley is



Photograph supplied by the Chicago, Milwaukee and Puget Sound Railway

LAKE KEECHELUS, IN THE CASCADE MOUNTAINS.

Showing snow-shed to protect the Chicago, Milwaukee and Puget Sound Railway, which skirts its shore.

Roundup, nicknamed the "Miracle of the Musselshell." The colloquialism is apt, since the first sod of this town was turned only in 1908, but in 1911 its population had grown to 3,000.

The river cuts a sinuous course through the vale, but the railway maintains as straight a route as the physical conditions permit for 120 miles. Some idea of the costly character of construction in order to preserve the grade and alignment though this valley may be gathered from the fact that the waterway is crossed no fewer than 115 times in the 120 miles, while several other crossings were avoided by diverting the waterway, the aggregate of such work being twenty miles. This stretch of track, it may be mentioned, is probably the fastest on the whole of the line, forming an ideal galloping ground for the "Olympian," the crack overland train of this railway.

When the route of this transcontinental was plotted it was found that at two places what may be termed as short local lines were already in possession. Leading apparently from nowhere to nowhere, they yet met the needs of those immediately contiguous. But they were not particularly prosperous concerns. One such line, known as the Montana Railroad, ran westwards from Lewistown, in the Judith Basin, via Harlowton, across the outer ridge of the Rocky Mountains. As this line could be utilised to a certain extent it was purchased, and thereby the new company was afforded means of penetrating the tortuous, forbidding, rugged Sixteen-mile Canyon of Montana.

By following the Musselshell River and acquiring the old Montana line the new railway was brought within easy reach of the wonderfully productive 2,000 square miles of land lying in a huge amphitheatre formed by the surrounding mountains, and known far and wide as the Judith Basin. The road leading to Lewistown is full of interest, inasmuch as a sharp ascent had

to be made to penetrate the outer rampart through a point known as Judith Gap. On the opposite side the descent was even more baffling in order to reach the above-mentioned town. The line had to be laid out in long loops and curves, finally making a huge horseshoe bend round the city to overcome the last sudden difference in level.

The Judith Basin is not only one of the most famous beauty and agricultural spots in the Middle West, but it has a stirring and romantic history. More legendary lore is associated with this huge glade than with any other spot for miles around. Here the various Indian tribes—the Sioux, Crows, Blackfeet, and Flatheads were wont to gather to hold their celebrations, war dances, powwows, and to draw up their plans of campaign for repelling the advance of the paleface. A shoulder of the mountain range, Black Butte, thrusts itself loftily and grimly into the sky. During the troublous times of half a century ago beacons blazed forth from this eminence to summon the tribes to war-paint and feathers, while, with its complete command over the surrounding country below, it was a favourite spot for the Indian scouts and outposts.

In later days, as the cowboys thrust themselves farther and farther into the wild and woolly West in the search for pasturage for their herds, the Judith Basin became quite a favourite grazing ground, though the watchers of the flocks were compelled to maintain an eagle vigilance and to keep their powder dry, so as to be on the alert for skirmishes and cattle raids. Some of the most daring and relentless of the cow-punchers domiciled themselves in this country and assumed the duty of exterminating the hostile Red Men. Their deeds and exploits often are related around the camp fires and in the homesteads of the present settlers. But the stories are not all hearsay, bandied from one to the other, and freely embellished during transit. Fragments of documentary proof of those troublous times

The Judith Basin.

Stories of the Past.

are carefully preserved, and these letters form illuminating examples of brevity, intelligence and picturesqueness. One shack was run by a David and Jonathan cowboy twain named Bill and Froggy. Bill had to go away on one of those periodical jaunts which were inseparable from cowboy life in those days, leaving his chum in solitary occupation of the shack and grazing ground. But he was not disappointed in news from home, although they were pre-mail coach days, as the following pithy letter proves. It runs —

“DEAR BILL,—

“A fellers passin by, an I got a chanst to send you a letter. Everythins been goin fine since you left. There was a Indian here yesterday. He was a chief. I shot im. He's dead. Potatoes lookin fine. Speet ter make sum more whisky termorrow,—Yours,

“FROGGY.”

But those roaring times have long since departed, and practically the whole tract of country is under peaceful settlement.

Although the Chicago, Milwaukee and Puget Sound Railway bought out the little line running from Lewistown, via Harlowton, to Butte, it did not press it into service to form part and parcel of the transcontinental. Its grades were too steep, and its curves too sharp for the overland traffic which was to come. But at the same time it offered a means of getting material into a very difficult country. New surveys were run through Sixteen-mile Canyon, and where the work could be accomplished quickly the old line was rebuilt, its kinks straightened out and its short, sharp rises flattened, while in parts the old line was abandoned completely, the track being torn up after it had served its purpose in conveying supplies to the building army scattered among a hundred or so camps. In order to save time, the builders were permitted to utilise the last section of the old road leading to Summit—the highest point touched by the metals in negotiating the Big Belt Range—despite the extreme severity of the grades, for the time being.



Photograph supplied by the Chicago, Milwaukee and Puget Sound Railway.

LAKE CHATCOLETTE, EASTERN WASHINGTON.



SIDE VIEW OF THE HUGE ROTARY SNOW-PLOUGH BUILT BY THE CANADIAN PACIFIC RAILWAY
FOR SERVICE AMONG THE ROCKY MOUNTAINS

The Snow-Plough and Its Work

HOW THE RAILWAYS FIGHT AGAINST THE TRACK-BLOCKING SNOW



IN countries which are liable to heavy snowfalls the railways are tied up under such visitations far more effectively than are those in temperate climes by the fog fiend. This enemy of the railway operator, despite the most valiant and herculean efforts, will oftentimes refuse to release its grip for days on end, bringing traffic to a standstill. The snow-shed offers an effective protection in mountainous districts where slides and avalanches are experienced, but upon open stretches of the steel highway the operator has only one course open to him—to fight his implacable enemy.

The scudding white fleece is no mean foe. It will fill a deep cutting to the contour of the country, and upon a level stretch will pile up huge hills which are not easily shifted. To force a passage by hand labour through such obstructions is a hopeless task; and in order to expedite the removal of the snow, so as to reduce the traffic interruption to the minimum, the engineer has devised wonderful mechanical appliances. Although they displace vast armies of men armed with shovels, the latter cannot be

dispensed with entirely. In fact, often gangs have to be rushed up to extricate the plough after it has become stalled in a difficult position, and perhaps can neither advance nor retreat.

The oldest and most common form of mechanical snow-shifter is the wedge plough. As the name implies, it has the form of a big wedge or a double scoop turned edge-wise with a sharp prow. Its lower edge is just clear of the rails, while in the largest types the top edge of the scoop is level with or above the topmost point of the driving equipment. In some instances, as upon the Scottish railways, it is a somewhat improvised apparatus, attached to the front of the locomotive; but such a system is applicable only in those districts where the obstruction is relatively insignificant, and is not packed tightly.

The method of operation is very simple. The pointed nose of the plough is driven into the drift or bank, when, merely by pushing it forward, the snow displaced by the prow is deflected along each side of the scoop, and thrown clear of the track. Sometimes the snow, which may have banked well after drifting, does not yield readily

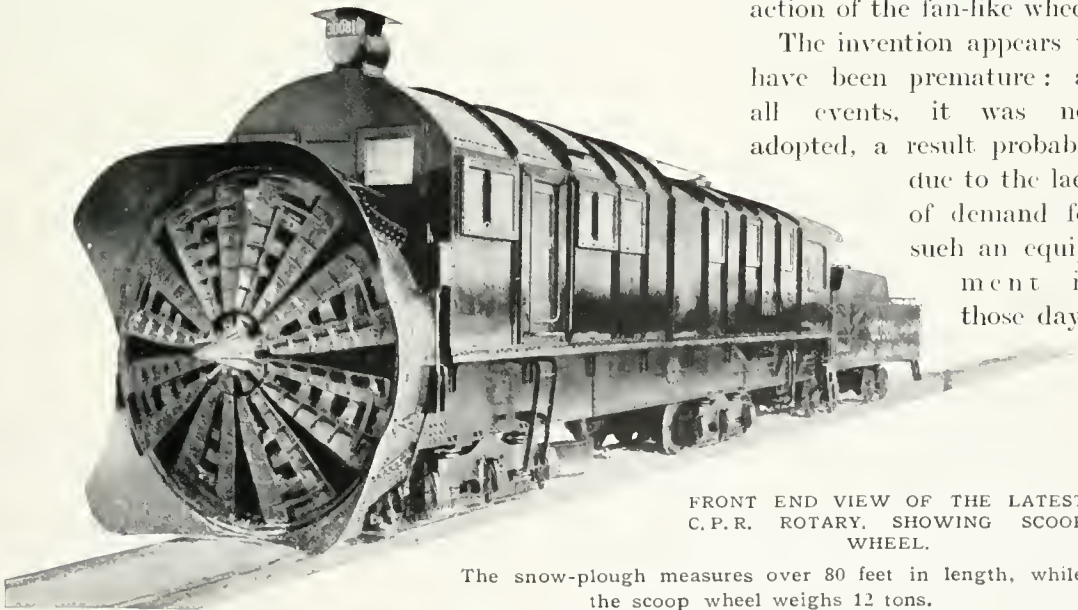
to the powerful sustained pressure of the locomotives behind. Then more drastic methods are adopted. The machine backs down the cleared track a short distance, and then drives headlong into the drift, this bucking being continued until either the bank is overcome or the plough is defeated. One great advantage of this form of snow-fighting machine is the speed with which the line can be cleared as compared with other methods, but its field of application is somewhat restricted. Deep drifts or banks in which layers of ice, arising from alternate thawing and freezing, and which always packs intensely hard, does not yield to such a method. The prow of the plough is apt to be forced upwards, and often the machine becomes derailed.

The wedge-plough is of very little use in mountainous districts where slides are prevalent, as the avalanches are apt to contain masses of rock, uprooted trees and other debris, which place this type of snow-fighter out of commission very readily.

The rotary is the railway engineer's finest weapon for combating the forces of winter, notwithstanding that at times the resistance is stern, the struggle for supremacy is bitterly contested, and progress is slow. Although in its present perfected form this tool is of comparatively recent date, the idea itself is by no means new, the first patent having been taken out 45 years ago. Perhaps it is not a strange circumstance, but the invention is of Canadian origin, and it was evolved, not by a railway engineer, but by a dentist! This was J. W. Elliott, a resident of Toronto, and he christened his conception a "compound revolving snow shovel." Fundamentally, it resembled the machines of to-day, since it comprised a truck on which was mounted a boiler and an engine for driving the disk-wheel, the apparatus being pushed by an ordinary locomotive into the snow. The idea was to bore into the snow in the manner of an auger and, by catching the displaced material, to whirl it clear of

the track by the revolving action of the fan-like wheel.

The invention appears to have been premature: at all events, it was not adopted, a result probably due to the lack of demand for such an equipment in those days.



FRONT END VIEW OF THE LATEST
C. P. R. ROTARY, SHOWING SCOOP
WHEEL.

The snow-plough measures over 80 feet in length, while the scoop wheel weighs 12 tons.

Shovel work would have to be practised under such circumstances but for the perfection of another wonderful appliance—the rotary snow-plough.

Later, however, another inventor, Jull by name, revived it. The main feature in this instance was a knife-wheel, which, cutting up the snow, passed it through to a fan-wheel

mounted behind, which ejected it through an opening in the casing. This device was taken up by Leslie Brothers, of Orangeville, Ontario, who constructed a full-sized machine. During the winter of 1883-4 it

This experiment served to suggest certain improvements, such as the ability to throw the snow to one side or the other as required. Another machine was built upon the improved lines by the Cook Locomotive



FRONT VIEW OF THE CHICAGO, MILWAUKEE AND PUGET SOUND RAILWAY'S HUGE ROTARY SNOW-PLOUGH.

Built by the American Locomotive Company. The wheel is 11 feet in diameter.

was tested by the Canadian Pacific Railway. The trial was scarcely fair, because the winter had broken before it was completed; but in order to ascertain what it could do, snow and ice were dumped into a cutting to give an approximate representation of a drift. The artificial snow-bank was not very deep, but sufficed to establish the invention, the snow being caught up and hurled through the air for some 200 feet.

Company, now amalgamated with the American Locomotive Company, and was put into operation upon the Union Pacific in the winter of 1887. By the aid of this first practical rotary blockades which had defied the railway's ordinary snow-fighting methods for weeks were raised in a few days. The very first run served to satisfy the railway that at last a reliable mechanical snow-fighter had been designed.

Through the enterprise of the American Locomotive Company, assisted by suggestions for improvements which have been extended by the men who have had to use the machines, and who thus are in the best position to discover weak points, the rotary has been brought to a high pitch

point in the reverse direction lying flat out of the way. The wheel is encased in a huge drum having a square hood fitted with a shoot at the top, through which the snow caught in the conical scoops is discharged into the air in such a way as to fall far from the line. This shoot is fitted with an



FRONT END OF WEDGE SNOW-PLOUGH USED UPON THE CANADIAN PACIFIC RAILWAY.

of perfection. In its present form the scoop wheel, which is the vital feature, comprises ten hollow, cone-shaped scoops, set radially like the spokes of a wheel. The surfaces of these conical scoops are quite smooth, so that the snow cannot possibly stick in any way. On the front side each scoop is open throughout its entire length, to enable the snow as it is cut up to be taken in. On each side of the opening, knives are hinged, and in such a way as to adjust themselves automatically to the cutting position and according to the direction in which the wheel is revolving, the knives which

adjustable cover which can be turned to suit the direction in which the snow is being thrown by the wheel.

The operation of the machine is very simple. The machine, its boiler and driving mechanism, are mounted upon a heavy truck, which is completely enclosed in a cab for the accommodation of the crew. By means of windows in the front end above the drum the pilot has a clear view of the snow ahead. All the controls are within immediate reach, including the steam whistle, by means of which, according to a pre-arranged code, instructions can be

communicated to the locomotives which are pushing the plough, as the latter is not self-travelling: its machinery is purely and simply for rotating the wheel.

The plough is pushed into the snow bank, the wheel being set in motion—about 150 revolutions a minute—before it touches the

heavy sudden jolt, and if the obstruction be a boulder or a good-sized tree-trunk, then the knives are torn off, or so damaged as to be useless. But the demands that the line shall be opened with all speed renders such accidents unavoidable, and unless the damage is extensive, no notice



GENERAL VIEW OF THE CANADIAN PACIFIC WEDGE SNOW-PLOUGH.

snow. The knife edges cut the snow, which, dislodged, is forced down the scoop until it reaches the periphery of the wheel. Further travel is prevented by the drum, and the snow can only escape when the end of the scoop comes opposite the shoot in the hood. The centrifugal force set up is sufficient to enable the snow to be thrown in a continuous fountain high into the air, and some 60 or more feet from the track.

Now and again obstructions will be encountered, and unless the fates are kind trouble follows. Sometimes the machine is derailed; but more often than not it is the knives which suffer. There is a

is taken at the moment. Repairs can be effected later at leisure. With the big drifts and banks where ice and snow have packed hard, forming a substance almost as dense as rock, bucking is practised. The plough with the engines backs down the track, and then the obstruction is charged. The pressure is maintained until the obstruction obtains the upper hand, causing the wheel to slow down, when the signal to back out is given hurriedly before there is an opportunity for the machine to become stalled. Bucking is continued until the machine drives its way through the packed mass, or is compelled

to acknowledge defeat. In the latter event there is no alternative but to turn to manual labour—to blast and shovel out the obstruction as if it were rock. On the steep mountain grades the battle between the railwaymen and the forces of Nature often is terrific. Four or five big locomotives, the rims of their smokestacks only just visible above the level of the drift, belching steam and smoke for all they are worth, and with the plough itself absolutely out of sight, though betrayed by the fountain of snow which it is spouting, are often required in order to achieve success; and the fruits of this herculean labour is revealed in the deep square-cut trench through the white wall, disclosing the tracks, and of just sufficient width to permit the waiting trains to pass.

To-day the snow-plough is practically standardised. The scoop wheel has been enlarged to 11 feet, the boiler pressure has been increased, and the machinery is of very great power. Knives fashioned from steel plate have been superseded by knives of cast steel, and are of greater strength and weight. The drum, too, has been improved and strengthened so as to be able to stand up well to the heavier duties imposed. Taken all round, the modern rotary is a formidable unit in the railway's fighting equipment.

Although all the railways of North America which traverse the great mountain ranges are compelled to maintain a battery of rotaries, and are engaged in grim struggles during the winter, probably the Canadian Pacific, owing to its more northern situation, and the heavy varied character of its mountain section, experiences the toughest task to keep its line open. In fact, the struggle became so fierce that those responsible for the maintenance of communication called for larger and more powerful machines in order to enable them to do their work more efficiently. "Give us a plough that will not break down, and

strong and powerful enough to drive through any snowbank, and we will keep the lines open."

The request did not go unheeded; its significance was appreciated. The railway company's engineers set to work, and they produced a snow-plough which probably ranks as the heaviest and most powerful rotary which has been contrived yet, and wherein one or two novel departures from existing practice have been introduced by Messrs. H. H. Vaughan and John Player, who were responsible for its creation. Some idea of its immense size may be gathered from the fact that the main frame measures 48 feet 4 inches over all, and is carried upon two six-wheeled bogie trucks, while its total weight in running order is 130 (American) tons. The frame is built upon bridge girder lines, and to the front end the drum is attached. Upon this frame is mounted the boiler, which is similar to that used in the Pacific Class M-4 Consolidation locomotives of the system, working at 200 pounds pressure, having 2,108 square feet of heating surface and 44 square feet of grate area. The conventional system of driving the scoop wheel through bevel gearing has been abandoned in favour of a direct drive upon the marine principle, the designers maintaining that this is a superior method. The vertical engine has cylinders 20 inches in diameter, with a stroke of 24 inches, and although of light design is of strong construction. The scoop wheel, which is driven at 400 revolutions per minute, weighs over 12 tons. The cab is of steel, with all bracing and so forth on the exterior, so that a smooth surface is presented within. This practice was adopted to mitigate the risk of injury to the crew in cases of derailment, which is one of the worst dangers to be feared in snow-fighting.

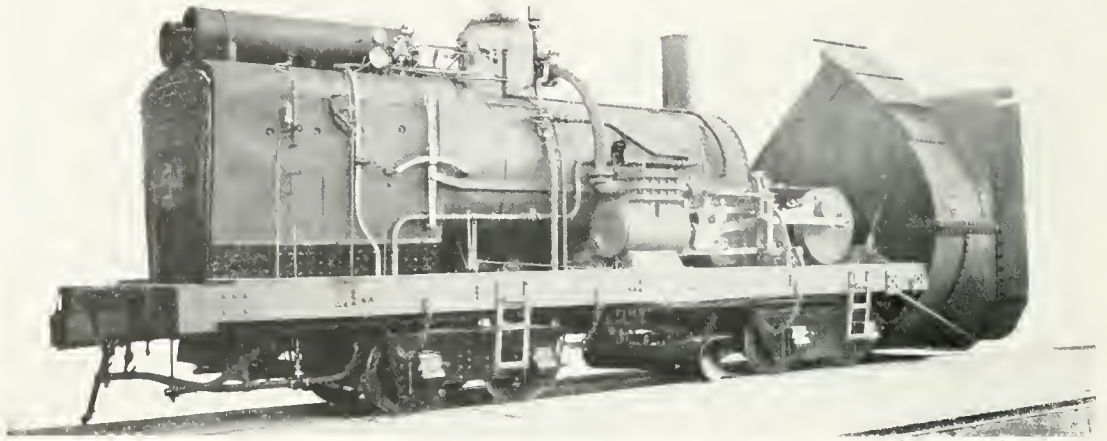
The Most Powerful Plough.

Attached to the plough is a tender of the locomotive type. It has been made especially long, measuring 32 feet over the frames,

The C.P.R. Demand.

and carries 16 tons of coal and 7,000 gallons of water, so that the total length over frames of this machine is over 80 feet.

was carried out therewith served to indicate that the forces controlling the mountain section of this railway had secured a plough



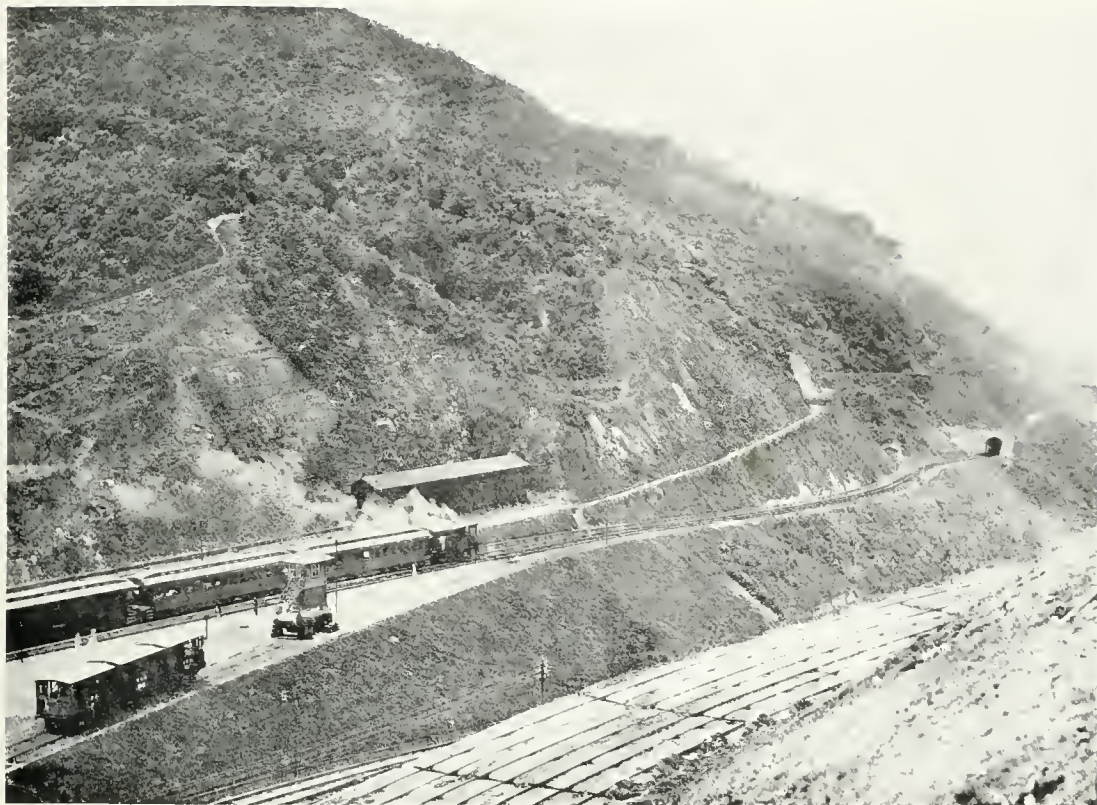
THE ROTARY UNHOUSED, SHOWING BOILER AND ENGINE FOR DRIVING THE SCOOP WHEEL.

Two of these powerful ploughs were built as a first instalment and were dispatched to the mountains immediately upon completion in January, 1911. Although the winter was not so severe as those experienced in previous years, and consequently an opportunity did not arise to submit the machine to a most exacting test to ascertain its capabilities, yet the work which

such as they desired. With the aid of only one locomotive instead of two, drifts of packed snow and ice 250 yards in length were forced with ease, speed being maintained from one end of the cut to the other. Ability to tackle the avalanche with its concealed trees was demonstrated also, because trunks 4 inches in diameter were cut up by the knives as if they were straws.



FRONT VIEW OF UNHOUSED ROTARY, SHOWING SCOOP WHEEL AND ITS DRIVING GEAR.



A BANKHEAD ON THE INCLINE SECTION OF THE SAN PAULO RAILWAY.

A Wonderful Brazilian Railway

THE STORY OF AN ENGLISH ENGINEER'S STRUGGLE WITH
PRIMEVAL NATURE



IN the early days of 1856, a number of distinguished Brazilian gentlemen, among whom was Baron de Mauá, received a concession from their Government for the construction of a railway from the seaport of Santos to the town of Jundiahy on the great inland plateau. The connection was required urgently as the fertile tableland and its commercial centres were cut off from the seaboard. In point of length the projected enterprise was not particularly striking, seeing that, as the crow flies, Jundiahy is barely 72 miles

from Santos, but, nevertheless, the provision of a steel link offered as teasing a puzzle in railway engineering as could be conceived. As far back as the early thirties the establishment of such a line had been urged and considered, to afford an outlet for the coffee crop, and the scheme had been referred to Mr. Robert Stephenson for his opinion and advice. Nothing came of that attempt, as the year 1839, in which it was advanced, was too early for such an enterprise.

Baron de Mauá, however, was more aggressive. He was resolved that the line should be built, and he even had preliminary

surveys run from Jundiáhy towards the coast under his own initiative. But his engineers only ran their lines roughly to the eastern edge of the plateau. There they stopped, not from lack of funds, but because they were baffled. The plateau tumbles precipitously into the sea, presenting a staggering cliff some 2,500 feet in height.

Thereupon Baron de Mauá sent to England to enlist the services, knowledge, and skill of the eminent British

A British Engineer Engaged. railway engineer, James Brunlees. But the Brazilian concessionaires had no intention of permitting the engineer to solve his difficulty as he pleased. Nothing but a locomotive line would be accepted; there were the two points which were to be connected with the shortest possible link of steel, and there were £2,000,000 available for the work. It either had to be completed for this figure, or the Brazilian concessionaires would go elsewhere. And for this sum no pioneer railway would be accepted, it had got to be a first-class line in every respect.

The British engineer, though aware of the severe stumbling-block which the Serra do Mar, as the granite cliff is called, offered to construction, accepted the onerous terms. His first question was the selection of an engineer to determine the route of the line. The circumstances demanded an engineer who had a railway eye for the country, was accustomed to working in mountainous districts, and thus qualified to grapple with the peculiar difficulties which were certain to crop up. The eminent engineer remembered one of his former pupils, Mr. Daniel Makinson Fox, who had been connected with some most difficult undertakings. At the time he was only twenty-six years of age, but he had demonstrated his ability in no uncertain manner, having assisted, among other enterprises, in laying out and constructing a narrow gauge railway in North Wales. There was another recommendation in this young engineer's

favour. He was conversant with Spanish, having mastered this language while spying out the land for railways among the mountains of the Pyrenees.

Accordingly, the young engineer was summoned to London, where the conditions of the undertaking were explained, and he was instructed to proceed to San Paulo to make the surveys for a locomotive line the cost of which was not to exceed £2,000,000.

Mr. Fox vividly recalls that Brazilian expedition. His knowledge of Brazil was somewhat hazy, but he did not worry his head about **A Depressing Start.** his pending work during the tedious sea journey, feeling sure that all anticipations would be shattered. It was a fortunate circumstance that he embarked upon his task in this spirit, because when he reached Santos, and came face to face with the Serra do Mar, he gave way to as severe a fit of despondency as could be imagined. The cliff appeared to be as impossible of conquest by a locomotive line as the Himalayas, and he conjured up visions of the £2,000,000 which had been set down for the whole 88 miles to Jundiáhy going in the climb up that escarpment. Nor did his spirits rise when he pursued the first task of an engineer who is dropped into a strange country. He questioned all those in Santos who penetrated the inland plateau as to the trails, paths and watercourses cutting through the Serra, but the information thus vouchsafed was of a meagre description.

The abortive result of these preliminary investigations proved only too conclusively that he would have to find out everything for himself. **An Exploration Trip.** There were no maps to guide him, so he had to become an explorer as well. He got together a small party of trusted natives to act as carriers, and to perform other varied tasks. Equipped with a good supply of axes and other tools, he

plunged into the dense forest which clothes the cliff from base to crest. The going was hard and slow. The virgin forest was dense and tangled—so much so that no sun ever penetrated the foliage to strike the ground. The rainfall was terrific, and, added to this, the Serra is torn in all directions by deep precipitous ravines, among which one had to scramble nimbly at the imminent risk of a fall and broken limbs. There was a heavy demand upon axe-work, and advance under such conditions was slow.

The exceedingly arduous conditions which prevailed demanded special arrangements.

A Noisome Jungle. It was impossible to drive straight ahead through the

forest from point to point, remaining in this timber prison until the opposite side was reached, owing to the difficulties pertaining to the commissariat, and the serious risk to health which it involved. So the engineer resorted to what might be described as periodical dives into the bush. He would load up his pack train with a large stock of provisions of a strictly limited variety—the prowess of the canner's art still remained to be revealed—making doubly sure that a goodly supply of tobacco was in the packs, and then would strike his route. At a suitable point in the bush a clearing was made, and a few huts of palmetto leaves run up for shelter from the rains and to offer a more or less inviting couch at night. From this camp narrow headings, virtually Indian trails, were driven in various directions, and the levels, and distances taken roughly. As a rule, three weeks were spent at a time in the jungle, which, owing to the absence of sunlight, generally was sufficient to bleach him like a stick of sea-kale. Then camp would be broken and a return made to Santos or some other convenient point, where he sojourned for about a fortnight, devoting his time unravelling the work and notes collected during the excursion into the jungle. On one occasion he was immersed

longer in the forest than he had anticipated, and when he emerged he was so pallid, thin, and drawn that his companions in Santos at once jumped to the conclusion that he had been stricken down with fever.

In this manner the engineer tramped up and down the Serra do Mar for month after month, but the discovery of a pass through the rampart **A Way Out**, appeared to be as far off as upon the day he first landed. One morning he descended through the trees a big fissure in the ridge, and at last he thought he had met success. The party struggled to the big, rugged V, and then disappointment hit them hard. It was a waterfall, and a sheer cliff on the inner side. However, it was a beautiful glimpse of rugged and wild Nature, and the engineer, dropping all thoughts of his railway for the time being, determined to examine the fall at close quarters. With infinite labour he scaled one of the perpendicular side walls and took a breather to enjoy the view unfolded from the top of the waterfall. The surveyor was sitting down smoking placidly, when his eye, idly following the valley spread beneath him through which the Rio Mugy flows, saw that the floor of the valley rose gradually to the north-east. He had trudged that valley previously, but from the bottom of the depression was unable to see what was now revealed. In a flash, he espied the only feasible route for the line.

The party hurriedly regained the valley, and then carefully drove a way along the route which the engineer had taken in with his eye from the edge of the waterfall. As he expected, it brought him to the top of the Serra, where a gap swinging through the mountain in a north-westerly direction brought him on to the plateau. Following this up, he gained a point on the highlands to which the Brazilian surveyors had brought their lines some years previously.

When the engineer had committed the results of his investigations to paper, and

had evolved his location, he found that he could negotiate the Serra within a distance of 5 miles. This in itself was a distinct

coming the steep ascent, which stamps the San Paulo as one of the most remarkable and interesting railways in the world. He



PASSING PLACE ON THE INCLINE, SHOWING UP AND DOWN TRACKS AND CABLES.

achievement, inasmuch as previous computations had indicated the necessity for a tortuous line of about 26 miles to overcome the cliff. But in this short length of 5 miles a difference in level of 2,550 feet had to be overcome. Such a sharp rise was dead against a continuous adhesion track, unless zig-zagging, V-switches, and other intricate solutions were incorporated. But they were impossible from motives of cost. As those were pre-rack-rail days, the engineer was thrown dead up against it. But as he was convinced that there was no easier path through the Serra, he decided to stick to his location.

Desperate situations demand drastic means of escape. So, foiled in the effort to get a grade not exceeding 1 in 40, the engineer conceived a unique means of over-

divided the ascent into four sections. In this way the trains would ascend and descend the mountain side in steps. As adhesion working was out of the question, he conceived a cable-hauling system. Each section or incline is topped by a short length of line 250 feet in length, falling downwards at 1 in 75, which is termed a bankhead, and at each of these points the stationary winding engines were to be placed. In this manner, four inclines, 6,388, 5,842, 6,876, and 7,017 feet in length respectively, were provided, each having a gradient of 1 in 9.75.

Fifteen months were occupied in the preparation of these plans, and then the engineer returned to England with his proposals. They were scrutinised minutely by the master-hand, and as the cost of build-

ing the railway upon these lines would not exceed the £2,000,000, Brunlees gave the ingenious solution of the problem his whole-hearted support.

The project received the approval of the company which had been formed to build the road, and construction was commenced. The young engineer, when he produced his surveys, did not fail to point out the fact that heavy excavation and development work would be unavoidable in sealing the Serra, and his statements proved to be not a whit exaggerated. When the railway builders appeared upon the scene, they found themselves faced by conditions which

has to cross an arm of the sea and two formidable rivers, both of which are subject to heavy and sudden fluctuations in level. For the first 8 miles a low embankment had to be raised to receive the metals laid on the 5-feet 3-inches gauge, the location paralleling the Government road laid across the marshes. A 500-foot bridge swings the line across the arm of the sea which separates the island on which Santos stands from the mainland; four 75-foot spans carry it across the Cubatao River, while three 66-foot spans lift it over the Mugy River.

But it was the incline division which



THE TWO INCLINES ON THE SAN PAULO RAILWAY.

The original line is in the foreground and shows the viaduct, 705 feet in length by 185 feet high.

seldom had been equalled in such operations previously. Although the going for the first 13½ miles out of Santos runs through practically level country for a greater part of the way, the land is marshy, and before it reaches the foot of the cliff

worried the builders. In the first place they had to drive roads through extremely rough country and dense forest to reach the camps scattered along the location, for the haulage of supplies and material. As the region was uninhabited, and for the

most part unexplored, reliance had to be placed upon the rough maps which the engineer had drawn up in preparing his surveys.

The railway in its climb to the plateau ascends the spur forming the east bank of the Mugy River. The sides of these mountains are torn and riven by gullies, chasms, couloirs, and rifts in the most fantastic manner, and as these run at right angles to the railway their negotiation offered many opportunities for ingenious thought, as did also the overcoming of the spurs and shoulders of treacherous rock forming the walls of these gaps. Some of the cuttings are of great magnitude, running up to 75 and 95 feet in depth. The trials of the builders were aggravated by the severity of the landslips and rock-slides, precipitated by the heavy rainfall. Time after time an embankment when completed for the rails was demolished. As a rule the earth could only be prevented from slipping by throwing up massive retaining walls varying from 10 to 60 feet in height.

After the line had been opened, one heavy landslide completely blocked a cutting, but it was removed in an ingenious manner. A mountain torrent was diverted so that it rushed into the cutting. Gangs of men were crowded on to the work, moving the soil, and the water, assisted by the heavy fall of 1 in 9.75 represented by the grade, scoured away the loose detritus effectively, economically, and expeditiously, leaving behind the heavier stone, which was utilised for building purposes.

At the foot of the fourth incline a deep chasm had to be crossed by means of a viaduct 705 feet in length, divided into ten 66-foot and one 45-foot spans, with the rail level, in the centre, 185 feet above the floor of the valley. Owing to the difficult character of the situation, the simplest means of erection had to be employed. A

Overcoming Landslides.

Grades and Curves.

wire rope was stretched across the rift, along which ran a block and tackle whereby the vertical members of the piers were placed. The spans were set by means of a crane, one by one, commencing from the south side, to which material was brought.

Although the railway traverses undulating country for 68 miles from the top of the inclines to Jundiahy, it is not free from extensive work. Heavy cut-and-fill prevailed for the first 12 miles from the Serra summit, with a maximum grade of 1 in 50, and curves of 1,320 feet radius, though that at the Serra summit, where the line swings sharply from the north-east to the north-west, is of 792 feet radius. On the inclines themselves the curves vary in radius from 1,980 to 5,280 feet. The hardest section of the plateau division is the 38 miles from San Paulo to the inland terminus, owing to the country being more broken. From a point 7 miles out of the first-named city the line cuts at right angles across a succession of rifts and ridges, entailing heavy cuttings, embankments, and bridging. Sharp grades were found unavoidable, the stiffest being 1 in 40, while in order to overcome the Belen summit a tunnel 1,950 feet in length had to be driven. On the north side of the tunnel a serious landslide menaced the safety of the line for a considerable time, and it was not until the treacherous earth was removed from beneath the metals in favour of a solid invert of stone 12 feet deep, made up in 8-foot lengths, that stability was secured.

The inclines are laid out upon an ingenious principle. Being worked upon the counterbalancing system, wherein one load descends while another ascends, a crossing has to be provided at a half-way point. On the lower part of each lift, an ordinary single track is laid, branching out into two tracks at the passing point, which are of sufficient length to accommodate the longest trains. But above the crossing there are three metals,

Bridge-building.

the centre rail being common to both up and down traffic. This arrangement permits of two lines of cable pulleys—one on each side of the centre rail—one for each load, while below the crossing only a single line of pulleys is necessary.

to the summit of the Serra. Four trips per hour thus can be made, though, if necessary, the journey could be accelerated by 15 minutes.

Although the railway has been in operation for nearly half a century, the incline



BANKHEAD SHOWING POWER HOUSE FOR DRIVING THE CABLES.

At each bankhead a pair of non-condensing horizontal engines of 150 nominal horse-power are installed to drive the winding machinery. The cylinders have pistons of 26 inches diameter by 60 inches stroke, and run at 22 revolutions per minute under a steam pressure of 30 pounds per square inch in the cylinders. The rope pulleys, 10 feet in diameter, are driven through friction gearing. A special brake wagon operating a clip brake is attached to every train running in either direction, and the train averages about four vehicles. The time occupied in the negotiation of each incline is about 15 minutes, or one hour for the ascent of 2,550 feet from the foot

system never has proved wanting, nor has an accident occurred. A few years ago, when the coffee traffic had outgrown the capacity of the older line, a new track was laid, roughly parallel to the first road, and also built upon the cable system. This line is laid somewhat higher up the mountain-side, the shoulders and spurs being tunnelled, while the rifts are spanned by heavy steel bridges.

Mr. D. M. Fox succeeded completely in keeping within the estimates, and the contractors completed the task ten months in advance of the specified time (eight years), for which they received a bonus of £43,750 from the Brazilian Government.



HOW THE SERRA DO MAR OF BRAZIL

The location of the San Paulo line over this formidable obstruction so as to enable trains to be lifted vertically trunk road because the vehicles are hauled by cables over the mountain range. To the left is the original



Photograph by courtesy of the San Paulo Railway.

IS CONQUERED BY THE RAILWAY.

2,550 feet within a distance of 5 miles constitutes one of the cleverest feats in railway engineering. It is a unique line, while to the right is the new road which became necessary to cope with the increased traffic



HEAVY TEN-WHEELED-COUPLED LOCOMOTIVE USED IN THE IRON ORE TRAFFIC OF SWEDEN.
The engine weighs $83\frac{1}{2}$ tons, the whole of which is available for adhesion.

Locomotive Giants—IV

SOME RECENT DEVELOPMENTS IN MAMMOTH ENGINES ON THE CONTINENT



DURING the past decade the iron ore export industry of Sweden has increased by leaps and bounds. The demand for this raw material and its economical transport to the points of shipment has taxed the facilities of the State railways to a supreme degree. The two foremost mining districts are those of Gellivare and Kiruna, in Lapland, which two fields supply more than one-half of the total output.

The extreme northern situation of these deposits in very uninviting, broken, and difficult country presented some pretty problems. While Gellivare is about midway between the waters of the Baltic and Atlantic, Kiruna is nearer the latter. On

the northern Baltic Sea is the Swedish port of Lulea, which was connected to the main railway system of the country by a road running north-eastward from Brücke on the Stockholm-Trondhjem line.

When the Scandinavian peninsula was under a common government it was decided to carry a new line from Lulea across the peninsula to Narvik, an excellent port upon the Norwegian seaboard, well within the Arctic circle. By so traversing the heart of the iron-mining country the two great producing centres would be brought within immediate touch of both the Baltic and Atlantic ports. The character of the country rendered the work one of considerable magnitude, while the technical difficulties which had to be overcome were of no mean



THE MOST POWERFUL LOCOMOTIVE IN EUROPE.

The Flamme Pacific, which handles the fastest express service of the Belgian State Railways, leaving Brussels for Ostend. The train load averages 400 tons, and a speed of 76½ miles per hour is attained.



order. Ultimately the Swedish Government undertook the longer and more difficult section between Lulea and Riksgransen on the Swedish-Norwegian frontier, while the Norwegian Government completed the short link between the boundary and Narvik.

The imperative necessity for carrying the ore from the mines to the shipping points—the bulk is dispatched from Narvik—at the lowest possible cost has brought about considerable developments in the transportation service. The weight and capacity of vehicles have been augmented; longer trains have been brought into operation; while larger and more powerful freight locomotives have been adopted. Steel 30-ton hopper wagons of the six-wheeled type are employed, while the

trains range from twenty-four vehicles upwards.

The locomotives are of the ten-wheel-coupled class, having a total heating surface of 2,109.75 square feet, with Schmidt superheater aggregating 634 square feet. The cylinders have a diameter of 27.5 inches and a stroke of 25 inches. The total weight of the engine in running order is 83.5 tons, the whole of which is available for adhesion and equally distributed over the five driving axles. The locomotive is equipped with a bogie tender, and its total length over buffers is 65 feet.

Probably one of the most arduous sections to work upon the Federal Railways of Switzerland is the St. Gotthard line, which includes the famous tunnel. The grades are exceptionally severe for a trunk steelway,



Photograph supplied by Swiss Federal Railways.

TO HAUL THE HEAVY EXPRESSES OVER THE ST. GOTTHARD PASS AND THROUGH THE FAMOUS TUNNEL, DOUBLE-HEADING IS PRACTISED. THE PILOT BEING A POWERFUL 4-6-0 MOUNTAIN LOCOMOTIVE.

while the curves are sharp. During the past few years the volume of traffic flowing over this steelway has risen by leaps and bounds, and more and more powerful steam locomotives have to be devised to cope with the situation.

The heaviest grades are encountered between Göschenen upon the north and Biasea on the south side of the tunnel. To move the trains in either direction over this section double-heading is practised, the road engine being assisted by a powerful pilot. Details of these giants have already appeared in this work (see pp. 561-2).

When one bears in mind the generally flat character of the country of Belgium, one scarcely would look to the railway system of that kingdom for the most powerful coal-burning express locomotive in Europe. Yet such is the ease. This distinction has been gained by means of the mammoth Pacifics of the 10 type designed by Monsieur B. J. Flamme, the eminent locomotive engineer, and the chief of the mechanical department of the State railway system. These creations are four-cylinder simples, and have since been divided officially into two classes—those built previous and subsequent to the year 1912 respectively. While the last-named class has slightly less aggregate heating surface, and is nearly 4 tons lighter, the tractive effort is identical in each instance. The following details refer to the most recent expression of this design.

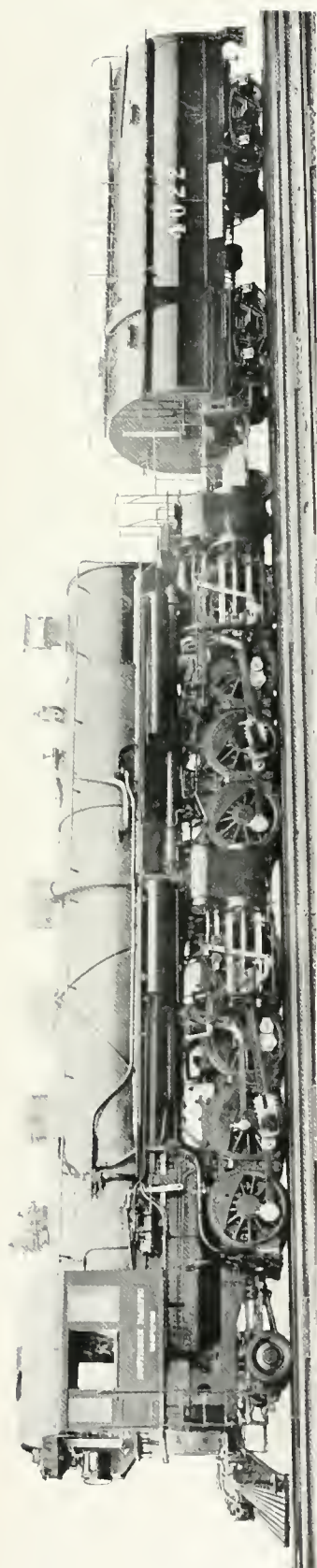
The diameter of the cylinders is 19·685 inches, while the stroke is 26·98 inches. The total heating surface is 3,246·3 square feet, of which aggregate the superheating surface is 667·36 square feet, while the fire-box area is 49·29 square feet. The drivers are 78 inches in diameter, and each driving axle carries 18·699 tons, giving a total weight of 56·097 tons available for adhesion. The total weight of the engine in running order is 96·45 tons, while the tractive effort is 33,435 pounds.

The six-wheeled tender carries 7 tons of coal and 4,872 gallons of water. These Pacifics are engaged in the heaviest and fastest mail service. The average weight of the train behind one of these engines is some 400 tons, but often it is increased very appreciably. Possibly the stretch upon which these monsters are able to show their paces to the best advantage is the 78 miles between Ostend and Brussels. This run is made in 90 minutes, including two stops, at Gand St. Pierre and Bruges respectively. Upon the reach of 25 miles between these two stations, where the conditions are peculiarly adapted to fast travelling, it is no unusual circumstance for this train, even with a load of 450 tons behind the locomotive, to notch 76½ miles an hour, while on the other parts of the journey 62 to 65 miles an hour are sustained with ease.

Some idea of the enormous strides which have been made in regard to the mechanical equipment of the Belgian railway system during three quarters of a century is demonstrated by comparing the huge Flamme Pacifics with the little pioneer "Le Belge," which was the first locomotive to run in Belgium in 1835. She was a crack steed of her era, and although she has long since been retired from active service, she still is preserved as an interesting memento of the days when railways were young upon the Continent. "Le Belge" is a six-wheeled engine, 17 feet 10½ inches in length (without tender), has a total heating surface of 355 square feet, and weighs 11½ tons. Whereas the pioneer exerted only 41 horse-power, the powerful Flamme develops no less than 2,300 horse-power. Incidentally, this locomotive brings home the price paid for power and speed, since she cost £5,000.

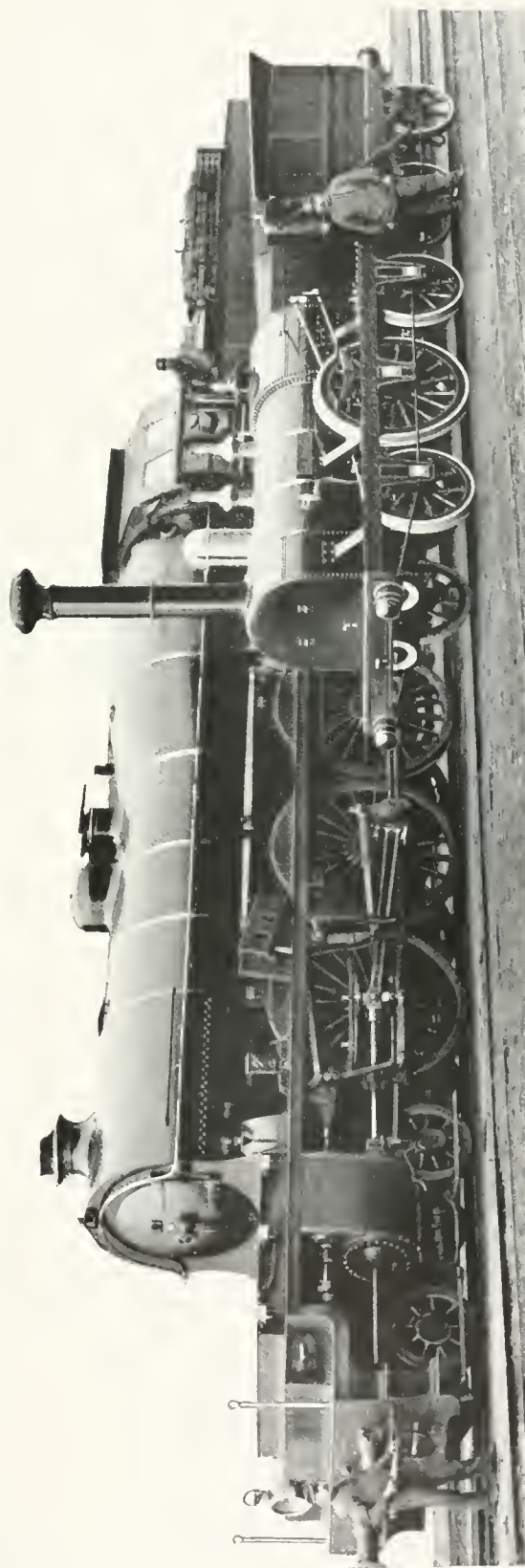
An Interesting Comparison.

While the perfection of the Mallet articulated principle has adequately met the requisitions of the operating department for bigger and more powerful locomotive effort,



2-8-2 MAMMOTH OIL-BURNING MALLET ARTICULATED FREIGHT LOCOMOTIVE ON THE SOUTHERN PACIFIC RAILWAY.

The cylindrical tender, carrying 10,000 gallons of water and 3,200 gallons of oil, is attached to the chimney end of the engine, while a driving cab is provided on the footplate. In running order the locomotive with tender weighs 306 (U.S.) tons.



1835 AND 1913 UPON THE BELGIAN STATE RAILWAYS.

"Le Belge," the first locomotive to run in that country, which developed 41 horse-power, standing beside the monster Fiamme Pacific, which exerts 2,300 horse-power.

it has precipitated its own peculiar problem. This is, the endurance of the fireman. The monsters of this class which are common to the American continent represent the limit to which this factor can be forced; physical capacity is stretched to its utmost in stoking and keeping the machine up to its work. Strenuous efforts towards the removal of this handicap are being made by the evolution of mechanical stokers, but although enormous strides have been made in this direction, perfection and reliability are still somewhat distant.

This problem, however, is possible of solution by the utilisation of liquid fuel,

and in the acquisition of huge
Oil-burning Mallet. Mallets for the heaviest freight

work upon its system, where stretches of the road are exceptionally arduous, the Southern Pacific Railway stipulated for an oil-burning machine. The tender is attached to the chimney end of the engine, the footplate being converted into a cab, such as those used in double-ended motor trains in this country. The point has arisen as to whether this situation of the driving position is likely to meet with the general approval of the engine-driver. Being at the extreme end of the locomotive, he is exposed to the full brunt of a collision should he be so unfortunate as to blunder into a preceding train. On the other hand, it is averred that the very fact that he is more exposed to the consequences of an error is likely to make him more than usually cautious and to induce him to pay attention to his signals.

The Southern Pacific oil-burning Mallet was built by the Baldwin Locomotive Company of Philadelphia, and is a huge powerful example of its class. It is of the 2-8-8-2 type, with high-pressure cylinders 26 inches

and low-pressure cylinders 40 inches in diameter respectively, and a stroke of 30 inches. The boiler, of the straight type, has an internal diameter of 84 inches. There are 401 tubes $2\frac{1}{4}$ inches in diameter by 21 feet in length and 401 feed-water heating tubes of $2\frac{1}{4}$ inches diameter by 63 inches long. The heating surface comprises fire-box 232, fire tubes 4,941, feed-water heater tubes 1,220 square feet respectively, giving a total heating surface of 6,393 square feet, in addition to a Baldwin smoke-box reheater having a superficies of 625 square feet. The grate area is 68.4 square feet.

The functions of the reheater are similar to those of the superheater, with this difference: whereas the superheater raises the temperature of the steam before it passes to the cylinders, the reheater reheats the steam after it has completed its work in the high-pressure cylinders, and before it passes into the low-pressure cylinders, where greater condensation occurs.

The outside driving wheels are 57 inches, while the centre wheels are 50 inches in diameter respectively. The driving-wheel base is 39 feet 4 inches, the rigid wheel base 15 feet, the total wheel base of engine 56 feet 7 inches, and of engine and tender 90 feet 4 inches. The complete weight of the engine in running order is 216.3 (U.S.) tons, of which 149.25 tons are disposed over the drivers, and thus are available for adhesion. The eight-wheeled tender, of the cylindrical pattern, carries 10,000 gallons of water and 3,200 gallons of oil. Its weight is about 89.7 tons, thereby bringing the complete weight of the machine, under service conditions, to approximately 306 tons.

The Reheater.



STEAM SHOVEL EXCAVATING THE BOTTOM LIFT OF THE BECKWORTH TUNNEL APPROACH, THE SUMMIT LEVEL OF THE WESTERN PACIFIC RAILWAY, 4,956 FEET ABOVE THE SEA.

“The Feather River Canyon Route”—I

SEVENTY-FIVE MILES OF RAILWAY WHICH COST £1,500,000



NO one except a madman would think of running a railway through the Feather River Canyon ! ”

This was the emphatic verdict of Collis P. Huntington at the time that momentous enterprise, the first transcontinental, was taken in hand across the United States from the populated East to the Pacific Ocean. When the scheme was projected Huntington and his colleagues were worried by one obstacle—how to cut their way through the frowning Sierra Nevada mountain chain, which constitutes a physical

boundary between the States of California and Nevada.

The promoters of the enterprise had extricated themselves from their difficulty by enlisting the services of Theodore Judah, a born railway pathfinder and engineer, living on the Pacific coast. He knew the mountain range intimately ; was aware that the natural passages through the towering ice-covered barrier were followed by the Indians in their periodical treks between the coast and the interior. So obviously he scored these rifts through and through. His wanderings took him along the banks of the Feather River,

where it hurtles and thunders for 150 miles or more through a narrow gorge. It was an ideal route for the railway, but there was one insuperable obstacle. The defile was so constricted, the foaming waters lashing both sides of the ravine, that there was no friendly natural foothold for the steel road. One would have to be cut every inch of the way, and the job was certain to be expensive. Money was scarce; the promoters of the railway were not prepared to indulge in heavy work. So Judah was compelled to abandon the Feather River passage for one farther south, although it involved steeper grades.

Judah, however, was not permitted to have his way without opposition. A contemporary engineer, Mr. A. W. **Keddie's Survey.** Keddie, also living on the western coast, knew more about the Feather River Canyon than any other engineer, because he had tramped it from end to end to discover the practicability of building an easy road for vehicular traffic. The Feather River is somewhat curious. The main arm rises high up among the snow-crested mountain tops, but subsequently, being fed by a number of subsidiary streams or "forks," it becomes a huge fan, each tributary forming a blade as it were, and cutting its own gulch. Young Keddie knew these forks, and, convinced that Judah had made a perfunctory reconnaissance, and that Huntington was making a colossal mistake, he endeavoured to induce a revision in the railway route through the mountains.

It became a somewhat stormy interview. The engineer and the financier wrangled for some time, but although the engineer advanced figures and sketches galore to substantiate his claims, the railway magnate, primed with Judah's reports, declined to be convinced. So, losing his patience, he dismissed the young engineer's suggestion as the figment of a fertile, imaginative brain.

Keddie, disgusted at the result of the

interview, collected his papers. As he bid the financier adieu he threw the parting shot: "Mad or sane, you can take it from me that sooner or later a railway will go through the Feather River Canyon, and then you will have to stand with your back to the wall to hold your own."

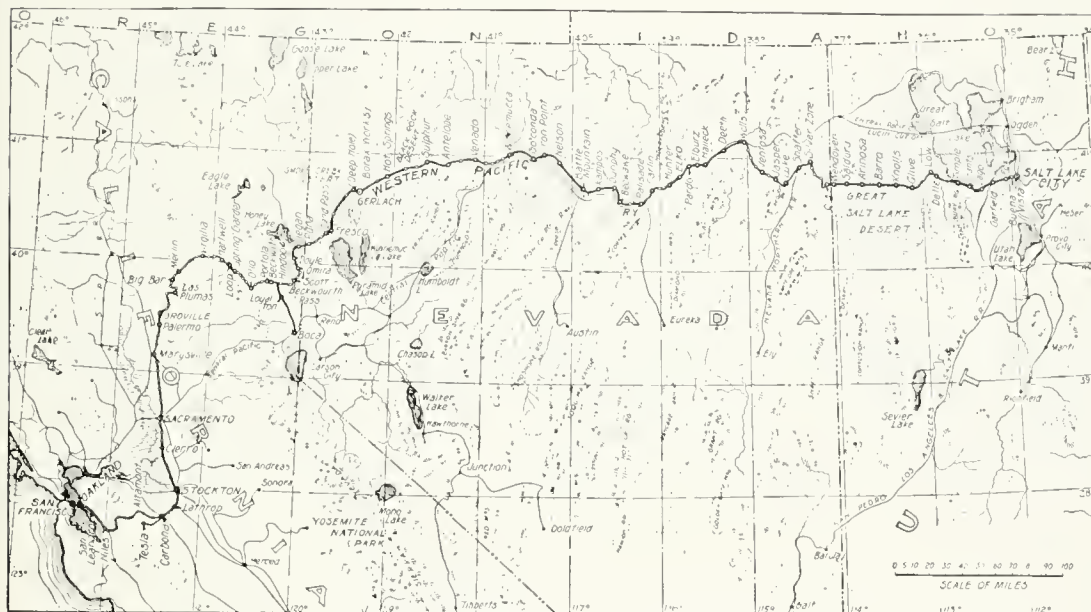
There the incident ended so far as Huntington was concerned, but Keddie was not the man to be thrown down by this cold douche. The **A Rival Line.** summation of the first transcontinental prompted a bevy of similar enterprises. Before the arms of the Central and Union Pacific Railways met on the shores of Salt Lake, a rival appeared upon the scene under the title of the Oroville and Virginia City Railroad, with Keddie as chief engineer. He ran his survey down the Feather River Canyon, and came back with a grade rising only 65 feet per mile through the Sierras, as compared with that of 116 feet per mile required to lift Huntington's railway over the obstacle.

This scheme failed to materialise, however, and nothing more was heard of the "Feather River Canyon Route" for twenty-two years. Yet there was every inducement to carry a steel highway through the Feather River country, inasmuch as it had built up a unique reputation. In the very early days the hardy, intrepid spirits trading with the Adventurers to Hudson Bay came down from South-west Canada to reap a rich harvest of furs in this wilderness of mountains. When the American fur trading companies arose to fight the British concern they likewise centred their efforts upon this territory.

It also figured prominently in a gold stampede during the Californian gold boom. A prospector named Stoddard **The Gold Stampede.** came back from the wild interior relating the discovery of a lake of gold. He succeeded in persuading a couple of dozen adventurous devil-may-care spirits to throw

their lots in with him, and the party tramped off into the hinterland to work the fabulous treasure-house of yellow metal. Others followed on their heels, and it became a ghastly, harrowing stampede. The trail was blazed with the bodies of fever-stricken miners who flocked from all parts of the world to sunny California. Many went mad and roamed the bush

of the railway. It is called "Humbug Valley." Stoddard and his party, after suffering privations and hardships indescribable, reached this depression, and the leader thought this was the country in which the lake of gold was situate. But though every square foot of country around was seratched, not a trace of colour was revealed by the drab mountain slopes or



THE ROUTE OF THE WESTERN PACIFIC RAILWAY BETWEEN SALT LAKE CITY AND SAN FRANCISCO.

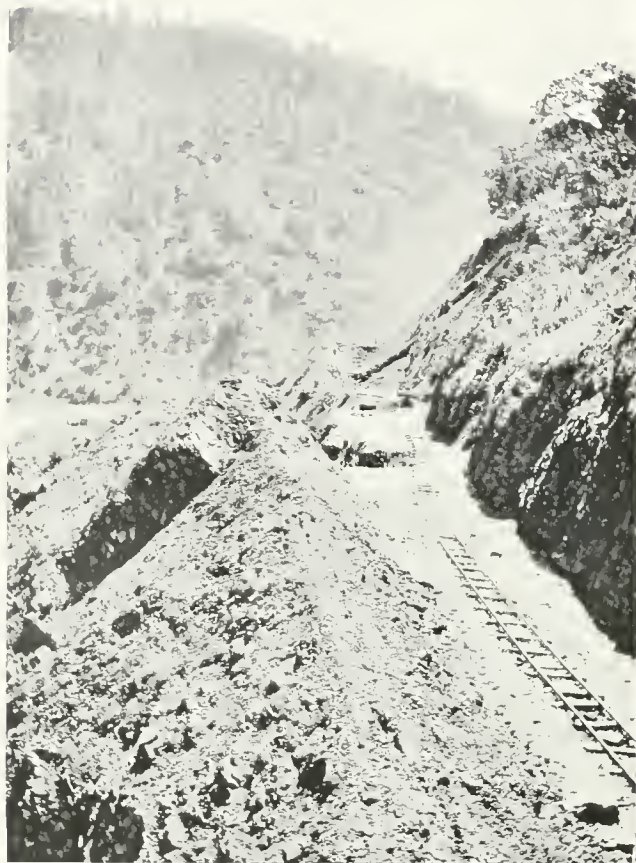
until death terminated their sufferings; others were lost in the timber Avernus; more fell from crags and splintered their skulls on the rocks below; the turbulent creeks swept scores off their feet when attempts were made to ford unknown depths, drowning them in the whirlpools or battering their lives out against snags and boulders; avalanches, rock-slides, and falling trees claimed their victims; and the Indians, who were hostile, counted seals by the score.

It was a terrible nightmare; the evil reputation of the gold trail into the Feather River country became known far and wide. Even to-day memories of that accursed lure are recalled on every hand. There is one smiling glen within a stone's throw

crystal sheets of water. In disgust they gave it the above nickname and left it for ever. A little distance away is another similar sward in the forest. Here the members of the party, coming to the conclusion that they had been hoaxed, rounded up their leader, expressed their opinion of his discovery in the mining vernacular, and with a view to refreshing his memory communicated their determination to hang him.

"Say, pard, this is your last chance. The lake or the noose. So look lively!" was the party's ultimatum.

Stoddard took the advice, both in letter and spirit. He was fleet of foot, sprinted into the bush, got away, and left his companions to get out of the wilderness as



DRIVING THE PERMANENT WAY THROUGH THE RUGGED MOUNTAINS 40 MILES EAST OF OROVILLE, CALIFORNIA.

best they could. To-day the scene of that dramatic episode is a fertile stretch of meadowland, known to all and sundry as "Last Chance Valley."

In 1892 another attempt to link San Francisco with Salt Lake City by railway was mooted. Once more Mr. Keddie was called in; once more he trod the labyrinths of the Feather River with his transit and level. He came back with a grade of $71\frac{3}{4}$ feet per mile. The project was discussed, but failed to escape the fate of its predecessor, owing to lack of funds.

Meanwhile other moves upon the American railway chess-board had been maturing unostentatiously. A new and strong hand gathered up the reins of the 1,600 miles comprising the system of the Denver and Rio Grande in Colorado. This

governing spirit had visions of railway conquest for the purpose of improving the position of his new acquisition. Why not throw out a long arm to the Pacific, thereby giving the mining country served by the Denver and Rio Grande Railway its own outlet to the sea?

Thus reasoned E. T. Jeffery, one of those strong railway organisers peculiar to the United States. He was spurred to action because E. H. Harriman had secured control of the first transcontinental railway, and was strengthening his power by buying up all the railways in the west to consolidate into a huge system. He had coveted the "Naboth's vineyard" in Colorado, but he was balked at every turn by President Jeffery. The latter first overhauled his defences by securing an entrance into Salt Lake City through the purchase of a connecting line therewith, before his opponent realised what was happening. Simultaneously he dispatched his forces to the west to

entrench themselves in the mountains, bidding them to work quietly so as not to arouse any suspicions. At the same time he embarked upon an unknown journey into the western country to satisfy himself that when the time came for him to show his hand he might be sure of his ground.

Prudence was essential. Had Harriman received an inkling of pending developments he would have seized the Feather River Canyon and Pass just to checkmate his rival. It would not have been a difficult matter. One of the moribund charters for a railway through that country could have been bought cheaply and revived. President Jeffery was aware of this possibility, so when he was confident of his position he instructed his engineers to secure possession of the

Feather River Canyon and the Beekwourth Pass, and in 1902 an innocent-looking concern known as the Stockton and Beekwourth Pass Railway came into being, with Keddie as chief engineer. Another company, known as the San Francisco Terminal Railway and Ferry Company, was formed also, the scheme of the latter being the provision of terminal facilities in San Francisco. When the latter was certain of its holdings President Jeffery, seeing that his net had been woven just as he contemplated, showed his hand. The two organisations were consolidated, and the Western Pacific Railway, an offshoot of the Denver and Rio Grande Railway, was born. Harriman was outwitted completely. He was too late to frustrate the enterprise, as his rivals were in occupation. All he could hope to do now was to prevent the money being raised for the work. But his silent antagonist had laid his plans only too well. Without undue exertion Jeffery raised £10,000,000, and at once let the contracts for the greater part of the work.

The Feather River Canyon was surveyed yet again, this time by Mr. Dillman, who superseded Mr. Keddie as chief engineer. He secured a location, somewhat to the north of that found previously by the latter, which, although offering cheaper construction, suffered from a short length of line with a grade of 122 feet per mile. This was not satisfactory. President Jeffery stipulated for a line which would not have a heavier rise than 52 feet per mile. When his requirements became known they were ridiculed widely, as the idea of conquering the formidable Sierras by such a grade was so staggering as to verge upon the absurd. But President Jeffery was convinced that

if Keddie had been able to find a route running up to 65 feet per mile in 1869, when railway engineering was still in its infancy, and that upon a reconnaissance, modern engineering science surely would enable 13 feet to be clipped off that result! True it would be costly; but nowadays first cost is a minor issue so long as the running charges are reduced. The former is secured once only, the latter effect is felt every minute of the day after the line is opened.

In 1905 Mr. Gould became interested in the project, and another survey was run under the direction of Mr. Virgil G. Bogue, who was appointed chief engineer. The financial interest controlled by Mr. Gould was sufficient to secure the comple-



THE MASSIVE CONCRETE PIERS FOR THE BRIDGE CARRYING THE WESTERN PACIFIC ACROSS THE MIDDLE FORK OF THE FEATHER RIVER.

tion of the line upon the plans laid down by Mr. Jeffery, and it was this alliance which led to the virulent war which broke out eventually between the Gould and Harriman interests, as it indicated the advance of the former into the latter's preserves.

The surveyors under Mr. Bogue had a trying and exciting time in the Feather

River country. The ravine is **Bogue's Survey.** merely a sharp V through the

mountains — a gigantic wedge-shaped crack where the river bubbles and roars, fumes and fusses from wall to wall. There was no trail—even the tortuous paths trodden down by the Red Men in times gone by had become obliterated by the undergrowth, rock-falls and other natural forces. Every fork of the waterway was searched from end to end; the surveyors made their way forward slowly and laboriously. The river itself could not be used as a highway for more than a hundred or so yards at a time. Canoes were useless; too much time, thow and sinew would have been wasted in carrying the frail barks round the unnavigable reaches. Consequently the men preferred to crawl on hands and knees through the scrub, to descend and ascend the mirror-like surfaces of the rocks with ropes round their waists, clinging like limpets to the slightest ledge and foothold as they carried out their work. Time after time the men had to be lowered over a projecting rock, steadying themselves in mid-air as best they could to manipulate their rods and instruments.

Narrow paths had to be hacked through the scrub to enable the straggling pack trains to come up with provisions. These were cached at convenient points, the men of a survey camp replenishing their travelling larder as conditions demanded. Now and again the surveyors would be caught at a disadvantage. They would run out of provisions and be too far from a cache to draw fresh supplies at once. Then they

had to make shift with what they could draw from Nature's larder. Fortunately the lakes, rivers and woods are well stocked with fish, fur and feather, so they did not go a-hungered.

When a towering cliff or rock could not be approached from the summit the men scaled it from the bottom, advancing one by one in an endless chain, with a rope passing from girdle to girdle, up the needle's side. When one is mountaineering under normal conditions such advance is arduous, but it is a hundred times more so when delicate instruments, chains and rods have to be carried as well.

When the surveyors were called upon to cross the river, and there was no friendly ford within convenient reach, they fashioned a crude raft from the prone trees lying around, poled themselves across the waterway, and then abandoned the primitive craft to its fate. Often miles had to be tramped up one bank to avoid a stretch of scurrying water in which it was impossible for a raft to live a second. Time after time a whole day was expended in making a crossing, taking the readings from a point immediately opposite, and then returning to the other bank.

The surveyors not only have to plot the path of the railway through such a country as this, but they have to keep a vigilant eye upon the various forces of Nature. The railways **How the Snow-line is Avoided.** which thread the Sierras at other places are troubled sorely during the winter by snow, the fall of which runs up to 250 inches or more during the months of December, January and February, the first month of the year being the worst. In the Feather River Canyon, however, the surveyors observed that the snowfall was less and laid longer on the one than on the other side. By dint of clever surveying they contrived to secure a location below the snow line on the sunnier side. One winter's observations—and it proved to be one of the worst winters on record—

at the Beckwourth Pass, the highest point reached by the line, showed only 13 inches of snow; on the Central Pacific, to the south, the railway was assailed by a fall of some 148 inches in the selfsame month. The result is that as yet no snow-sheds have been found necessary on this railway.

Yet, although the surveyors plotted a line below the snow, they took good care to secure immunity from the ravages of the river below.

The Feather River.

The Feather is a fearsome waterway, not only from its velocity, but from the extent and sudden character of its fluctuations in level. It is fed both by the melting snows on the mountain-tops and also by the heavy rain incidental to the Pacific seaboard. The result is that a rise and fall of 10 feet in as many hours in the level of the water is by no means uncommon, while the extreme variation between low and flood levels ranges up to 45 feet. When in flood the waterway is a furious nightmare: a bubbling mass of foam, rushing along here with tremendous speed as it falls over 100 feet per mile, whirling and skirling round sharp corners, and there rolling along placidly enough as its descent is just sufficient to carry the water away. Where the river runs its fiercest nothing short of hard, solid rock can withstand its force; all the soft parts of the banks are eroded completely, leaving big gaps and niches in the mountain flanks.

The surveyors found it impossible to keep to one side of the canyon. At places the cliff was too steep to offer any possible chance of cutting a path for the track; or else the waterway doubled upon itself so sharply as to demand a swing from one to the other side of the gorge. Yet, when the fieldwork was unravelled by the chief engineer, he found that the requirements of his superiors could be met completely. At no point need the grade exceed 1 in 100 throughout the 116 miles down the Feather River Canyon between Oroville and Portola. This location ranks as one of the finest

railway engineering achievements in the United States, since no other line gets through the Sierras with less than 105 feet per mile, either westwards or eastwards.

The Beckwourth Pass was seized because it offered the railway the opportunity to cross the “Continental Divide” 2,000 feet lower than on the Central Pacific, where the locomotives have to climb 7,018 feet towards the clouds. The summit is overcome by a tunnel—the longest on the line—bored through the crest for 6,006 feet. East of the mountain the survey did not offer particularly imposing difficulties, except for the stretches across the Nevada Desert, where discomfort was suffered from the scorching alkali sand, the temperature of an oven during the summer, and blinding dust storms.

The railway has its eastern terminus at Salt Lake City, where it connects with the Denver and Rio Grande system.

Then it strikes to the south- **Salt Lake.** west, following the shore-line.

This saline expanse is one of the puzzles of Nature. It is a big saucer of dense salt water, which has been shrinking steadily in volume for centuries past; in fact scientists have indulged in calculations to prophesy the date when water will be seen no more, basing their figures upon the present rate of shrinkage. As the engineers did not desire to make too sweeping a detour round the lake's head, they ran the track across the shallows for a distance of seven miles, anticipating that within a few years the permanent way would be left high and dry. A low embankment had to be built, for the simple reason that otherwise it would have been necessary to have hauled the ballast from a long distance. The immediate vicinity failed to supply more than limited quantities. The navvies could not excavate to more than the depth of a spade without coming into contact with water.

Railway building along these shores is faced by another difficulty. The bed of

the lake is only fine sand and silt, which is not capable of supporting a weighty embankment. Erosion and settlement are very active, the surf in particular wearing away the fine earth and small stones very speedily. But in this case, as the water-line would be some distance away in the course of a year or two, according to scientific calculations and observations, the engineers built a wide, low embankment upon which the constructional track was laid, this being lifted from time to time as settlement occurred.

But the scientists were found to be sadly erring once again. The lake, instead of continuing its steady, persistent shrinkage, suddenly changed its mind, owing to heavy driving rains and the activity of subterranean springs. The track was not placed in serious danger from this cause, but blustering winds coming from the north threw the water against the line, causing it to carry away the light soil form-

ing the sub-grade. The lapping wavelets coming in rapid succession did more damage than heavy rollers, as they exercised a continuous irresistible scouring action which undermined the temporary track.

It looked as if the whole seven miles of track were doomed, but the builders, by concentrating large gangs upon the ballast pits and trains, were able to hurry up load after load of heavier soil, such as coarse gravel. This was discharged overboard upon the track. The metals were buried in the process, but the lifting gang, after a train had shot its contents, hurriedly raised the track above the debris, ready to receive the next load. By this alternate dumping and lifting the metals were brought well above the surface of the lake, while, the embankment being widened and the slopes dressed with rip-rap, all the washing action of the surf was stopped. The embankment packed into a solid mass, and to-day it is as firm as a rock.



CARRYING THE WESTERN PACIFIC PARALLEL WITH THE MIDDLE FORK OF THE FEATHER RIVER.
90 MILES EAST OF OROVILLE



Photograph by Neurden.

THE GABARIT VIADUCT ACROSS THE TRUEYRE GORGE.

Designed by M. Eiffel, this bridge is 400 feet above the floor of the rift. The span is 541 feet.

Some Notable Bridges

HOW ENGINEERS HAVE TRIUMPHED OVER NATURE



IN the eternal struggle to maintain the straight level line, and in the removal of the kinks from the railways which were built in a hurry to meet present-day requirements, the bridge-builder has been called upon to perform heroic work. But in order to do justice to the achievements of the bridge-building engineer volumes would be required, because each big undertaking of this class possesses its own exciting story of difficulty overcome.

Not many miles distant from the Fades Viaduct, spanning the Sioule River, in the south of France, which, as already mentioned, is the loftiest bridge in the world,

is another striking example of daring engineering. This is the Gabarit Bridge, designed and built by Monsieur Eiffel, whose tower in Paris is probably the most familiar steel structure in the world.

When the Midi Railway set out to carry its line from Marvejols to Neussargues, the plotters found the lofty tableland which it was decided to cross to be interrupted by a huge fissure known as the Arcemie Valley. Owing to the depth of the ravine the first proposal was to descend by a circuitous route from the high level on the one side to reach a lower point in the rift, to span the latter at this place with a bridge, and to make another winding laborious re-ascent to the highlands. But when this

location was run over by Monsieur Boyer he did not agree with this solution of the difficulty. Why not carry the railway directly across the Trueyre Gorge, as it is called, thereby preserving the alignment and grade? It was an exceptionally bold proposition, inasmuch as it would bring the metals 400 feet above the floor of the rift, while, owing to the physical characteristics, a span of 541 feet would be necessary, and the bridge itself would have to be some 1,754½ feet from end to end.

At that time no work of such magnitude ever had been attempted, but there appeared to be no technical reason why it should not be accomplished. The colossal size of the structure alone was the deterrent. Still, the authorities were convinced that, if the right man were found to design and superintend the work, it could be carried through to success. Monsieur Eiffel had completed a notable bridge at Douro, in Portugal, which had aroused worldwide attention, and it was felt that he was the engineer to carry out this project. He accepted the undertaking, and he presented a design closely analogous to that which he had completed in Portugal. While the valley is somewhat precipitous on the Neussargues side, it slopes upwards more gently on the opposite bank. Accordingly, on this latter bank it became necessary to introduce four steel towers, supported upon massive masonry piers, to approach the main crossing of the waterway. The fourth steel tower, from the pier of which springs the arch, is 116 feet in height, as is also that on the opposite side of the gorge, which likewise supports one extremity of the arch span.

The arch, which is built upon the Eiffel system, has a depth of 170½ feet, while the span is of 541 feet. The superstructure comprises two straight lattice girders, 17 feet in depth. The permanent way for the metals is laid 5½ feet below the upper chords so as to prevent the railway vehicles

running off the bridge in the event of a derailment. Beneath the track is another road provided for the running of small hand cars for service purposes—painting, repairs, etc. The total weight of metal worked into the structure is 31,429 tons, of which the superstructure absorbed 13,260 tons, while the weight of the arch is 11,785 tons.

While the lofty French bridge was in course of construction a huge viaduct was completed in the United States in order to span the Kinzua Valley. Bridging this gap demanded a structure 2,953 feet in length, supported upon 110 iron columns, forming 21 trestle towers and supporting 41 spans. Each clear span was 61 feet in length, while each pier span was of 38½ feet. The highest metal tower was 297 feet, the average height of the piers being 176 feet.

The Kinzua Viaduct.

The spans were set by means of a specially designed crane or derrick. The track was completed to the north abutment. The crane set the first span trusses, which were bolted securely to the top of the tower on which it rested. A temporary wooden floor was then laid, upon which rails were placed and the crane moved forward the length of the span to set the trusses of the succeeding span, which, when finished, enabled the derrick to be moved forward to enable the first 61 feet clear span to be placed, which was done by drawing the trusses forward, this cycle being repeated to the opposite side of the valley.

The most remarkable feature of this undertaking, wherein 1,560 tons of iron had to be handled, in addition to 45 tons of steel for the track and fastenings, was the speed with which it was completed. A force of 125 men was employed, and aided by two steam hoisting engines and 30 miles of Manila rope, set the whole of the metal in four months. In the course of a few years, however, the traffic

A Record Building Feat.

had quite outgrown the strength of the structure, with the result that it had to be rebuilt, a task which was achieved satisfactorily under traffic conditions.

The Kinzua Viaduct ranked as the highest structure of its class upon the American continent for some seven years, and then it was deposed from premier position by the Loa Viaduct, which was built over the river of this name to take the Antofagasta Railway into Bolivia. The Loa River runs through a rugged canyon, and although the surveyor strove hard to find a location which would avoid the bridging of this deep gorge, he did not succeed. Accordingly he planned the viaduct 800 feet in length, with the rails 336½ feet above the waterway. The situation of this structure is probably unique, inasmuch as it is built at an elevation of 10,000 feet among the Andes, where the winds blow with terrific fury, but where the weight of the atmosphere is only about two-thirds of what it is upon the sea-shore.

The designs called for a structure containing 1,115 tons of iron supported upon seven iron towers, the length of the highest of which is 314 feet 2 inches, to support 80-foot spans. The ironwork was fashioned in England, together with a crane having a jib 50 feet in length, capable of swinging the longest main girders of the spans, which weighed nearly 10 tons.

The method of erection was ingenious. Two steel ploughing ropes, 800 feet in length, were strung across the gorge, on which a carrying truck was drawn to and fro by means of steam winches. The metal and other material for the towers was run out by means of this truck, and when over the required point was lowered into position. Only two engineers were dispatched from England to superintend the work, whatever labour that was required being recruited in the country.

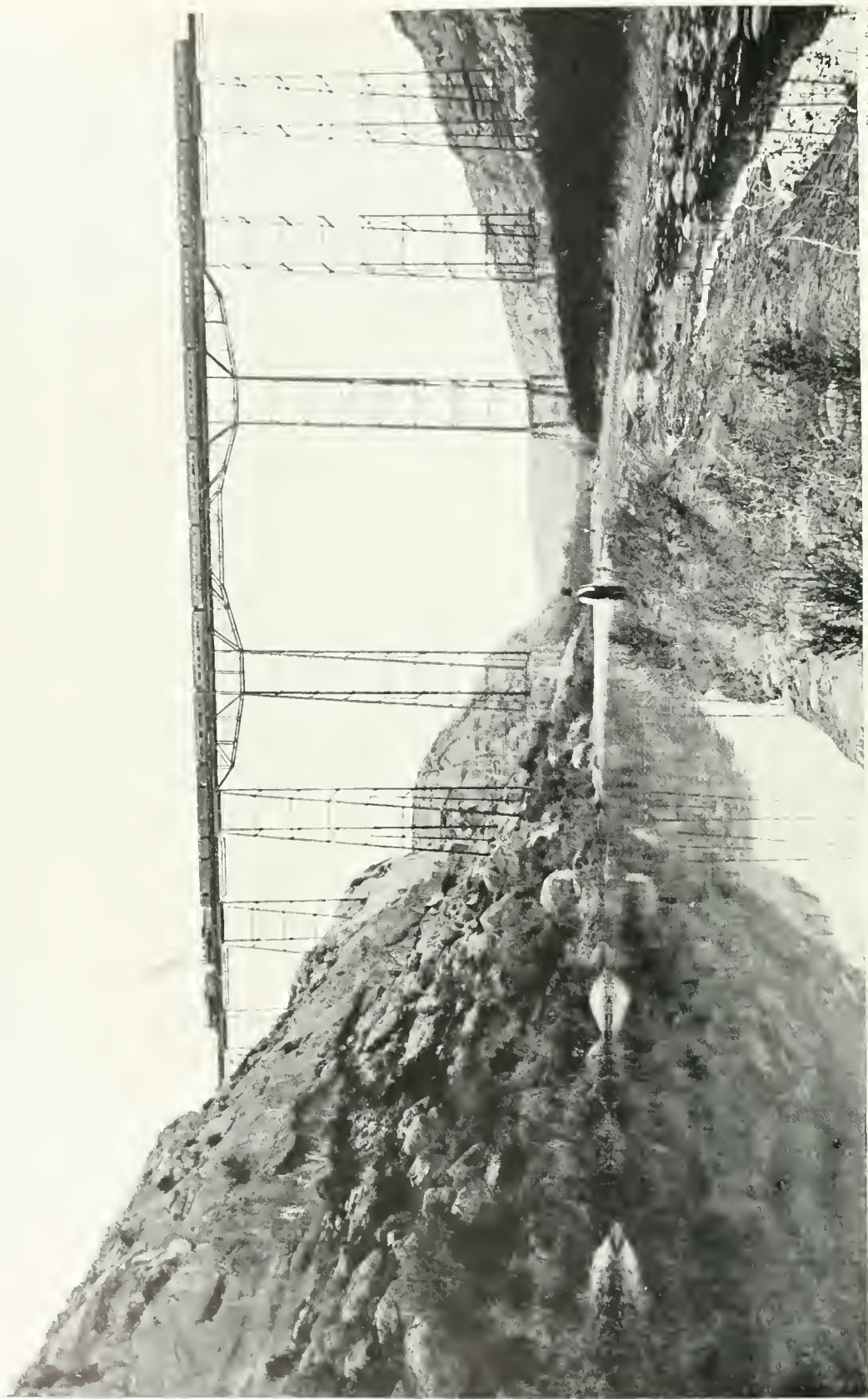
Shortly after the aerial line was set up it

was submitted to an unexpected task. It was desired to get a locomotive and building material to the opposite side of the gorge, so that railway construction might proceed while the viaduct was under way. It was impossible to swing the engine intact, so it was dismantled. Even then this left the boiler, representing a small item of several tons, to be transported. There was some doubt as to whether the cables would stand such a weight, but it was decided to run the risk. The boiler was slung and sent forward. The cables creaked and groaned ominously, and when the weight was near the middle the sag in the line indicated a possible sudden snap, and the precipitation of the precious boiler to the bottom of the canyon. But the ropes held out, and the boiler was hauled in and landed.

When the towers were completed the setting of the spans went ahead. The crane was brought up to the abutment, and the first pier span was set. A special set of rails was then laid upon the placed girders and the crane moved forward to take the main girders of the next 80-foot span in hand. These laid, the crane moved forward to the next tower, to repeat the operation, and so on until the opposite side was reached. The crane itself was worked by hand, and the setting of each girder was accomplished in a few hours. Despite the disadvantages under which the two supervising engineers suffered, the bridge was completed in about nine months, and that without any serious accident or the loss of a single life.

In the late 'eighties the Southern Pacific Railway decided to re-align its road between Shumla and Helmet in Texas, so as to save 12½ miles, and to avoid the danger and expense of working a line through the Rio Grande canyons. But in the revision it was faced with one serious obstacle—the Pecos River. This waterway has carved a course through a rift some 300

The Pecos Bridge.



Photograph by Brack.

THE RAILS OF THE PECOS HIGH BRIDGE ON THE SOUTHERN PACIFIC RAILWAY, 219 MILES WEST OF SAN ANTONIO, ARE 321 FEET ABOVE WATER LINE; THE CANTILEVER SPAN IS 183 FEET IN LENGTH.



SETTING THE STEEL OF THE BATTLE RIVER VIADUCT OF THE GRAND
TRUNK PACIFIC RAILWAY.

to 400 feet in depth. The company, however, decided to incur the bridging of the Pecos, the advantages of this location, all

8 feet less in height than the Loa River Viaduct.

The viaduct follows the usual American



Photograph by F. Bremner, Quetta.

BRIDGE ACROSS THE CHAPAR RIFT, ON THE NORTH WESTERN RAILWAY OF INDIA.

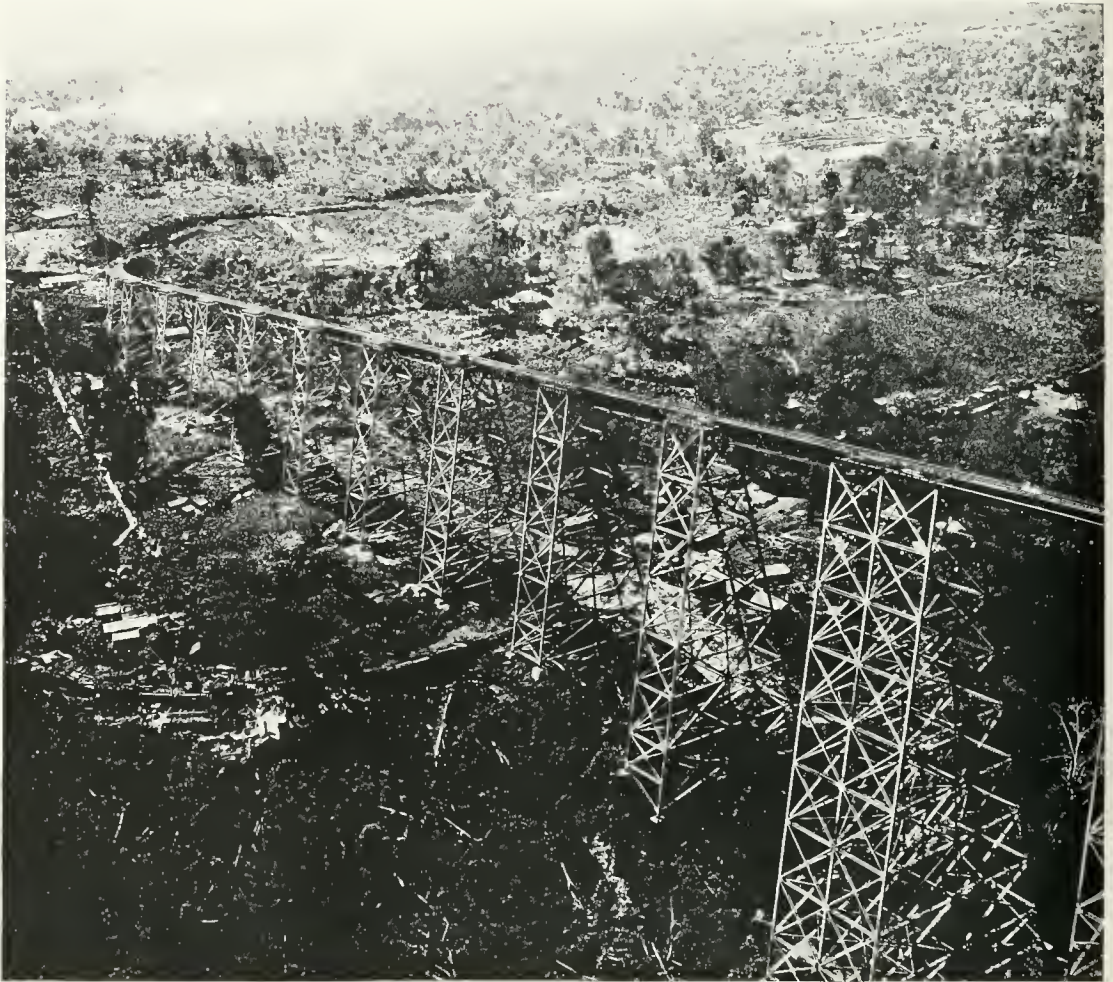
The rift is 150 feet in width and 234 feet deep.

things considered, being overwhelmingly in its favour. The point of crossing ultimately selected called for a structure 2,180 feet in length, with the rails 321 feet above the level of the water, so that the bridge exceeds the Kinsua Viaduct, and is only

design, comprising masonry piers supporting steel trestle towers, the principal of which is 269½ feet in height. The viaduct is divided into forty-eight spans, the pier spans being 35 feet and the clear spans 65 feet in length. The river itself is bridged

by a cantilever 185 feet in length. At the rail level the viaduct is 20 feet in width, so that there is not only space for the track, but a side walk on either side for the use

susceptibility of the low-lying banks of soft, friable soil to extensive erosion, and the velocity of the scurrying waters during the flood seasons, have combined to offer



Photograph by permission of the Pennsylvania Steel Company.

THE GOKLEIK VIADUCT, BURMAH.

This bridge is 2,260 feet in length, and has a maximum height of 320 feet.

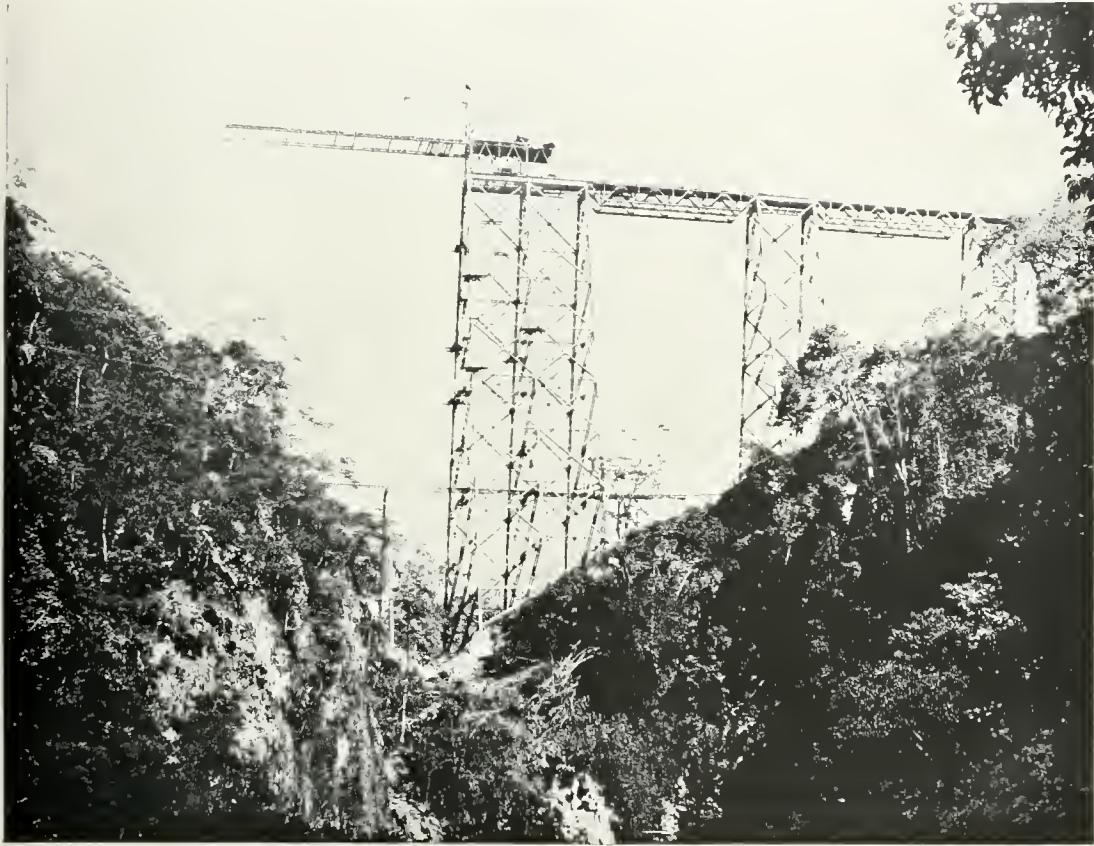
of the railway employees. Built in 1892, the bridge was designed for the heaviest train service, but the increase in the size and weight of locomotives and rolling stock rendered the viaduct out of date, the result being that it has undergone recent reconstruction, this work taking place without disturbing the train service.

India is a country where the bridge builder probably has accomplished some of his greatest achievements. The enormous width of the Indian waterways, the

the engineer some very pretty problems. The result is that many of the longest bridges in the world are to be found in the country. While the majority perhaps follow the general designs, many are carried out upon quite original lines, such as the Lansdowne cantilever bridge carrying the North Western Railway over the Indus into Sukkur. But possibly one is more impressed by the bridge-builder's daring when one penetrates to the wilder interior of the country, as revealed, say, among the fast-

nesses of Baluchistan. The plotting of the North Western Railway through the Bolan Pass is regarded as one of the finest pieces of work ever achieved by the railway surveyors. It is doubtful if any bridge will

150 feet in width, but there is a sheer drop of 234 feet. How to set the steel demanded considerable thought. Scaffolding and false-work such as had been possible with other bridges up to this spot were quite out of



BUILDING THE GOKTEIK VIADUCT, BURMAH.

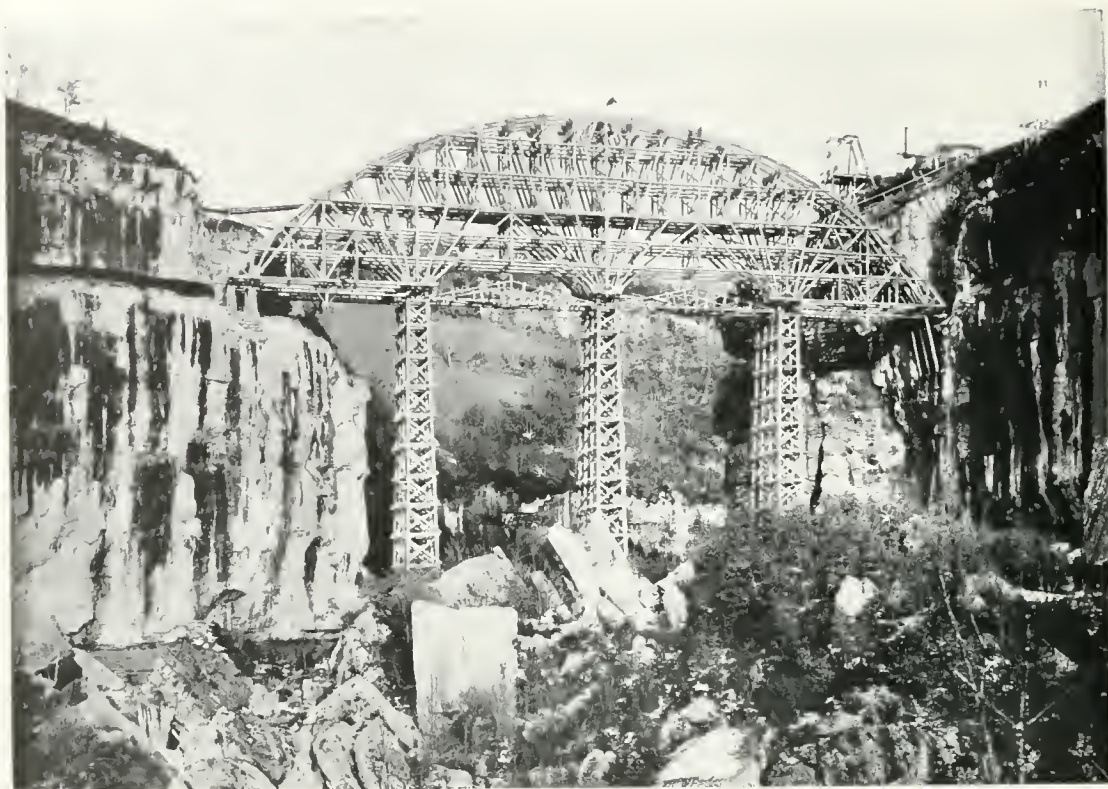
Photograph: Pennsylvania Steel Co.

The photograph shows the traveller by which the steel towers were built and the spans placed in position.

excite the interest of the ordinary traveller so much as the one spanning the Great Chapar Rift in the Dargai country. The wild environment and the daring of the plotter and builder here are revealed very impressively. The Chapar Rift is little more than a crack in the earth's crust through which a narrow stream makes its way. In order to preserve the grade the line had to be carried over a viaduct to the brink of the gorge, the short spans being supported on masonry towers built of material quarried in the vicinity.

At the point of crossing the rift is only

the question, while the issue was complicated still further by the wild fury of the winds which whistle through this constricted funnel. This latter factor proved that any attempts to build upon the traveller system would prove extremely risky. Accordingly a novel solution of the erecting difficulty was evolved. From the cliff face on each side of the chasm temporary overhanging platforms were built out for a certain distance, one being disposed on each side of the space to be spanned. Four spare girders were laid in an inverted position, and when completed



THE MONTANGAS BRIDGE IN COURSE OF CONSTRUCTION.

Showing the temporary wooden towers, 133 feet high, and the heavy timber centering ready for the masonry.

they were moved carefully and slowly forward until they met in the centre. In this manner they constituted temporary cantilevers, upon which a platform was laid, whence the erection of the bridge proper was carried out in perfect safety. When the steel span was set the temporary girders were hauled back and the overhanging platforms demolished.

In Burmah another notable structure is to be seen. In pushing northwards from Mandalay the Burma Railway found themselves baulked by the gorge through which thunders the Chungzoune River. It is no ordinary gorge, since the waterway disappears from sight, to follow a subterranean course 825 feet below the railway level. Thus a natural bridge is offered, but this is the floor of a valley some 300 feet deep. Consequently in order to preserve the grade a viaduct across the depression was essential.

This Gokteik Viaduct aroused considerable attention at the time of its erection because the contract was handed over to an American concern, the Pennsylvania Steel Company, of Steelton, but exigencies of time combined with cost precipitated this state of affairs. The designs called for a structure 2,260 feet in length, by 320 feet maximum height. The viaduct comprises two 120-foot lattice girder connecting spans and seven 60-foot plate girder connecting spans supported upon 15 steel towers. At both ends the viaduct is set upon a curve. The height varies from 130 and 213 feet at either end to 320 feet, this being the highest tower. A double track is provided for railway purposes, together with a highway for pedestrians. The material as it arrived at Rangoon was dispatched 400 miles up country over the narrow gauge line to Mandalay, and thence to the gorge. Work was interrupted

severely by the torrential rains, which frequently washed the line out of existence, one consignment slipping off the metals into an adjacent rice field, much to the owner's disgust. The undertaking gave employment to some 400 to 500 natives, in addition to a staff of Americans, and the placing of some 4,000 tons of steel was completed satisfactorily in about nine months.

The negotiation of a busy waterway is always beset with many peculiar difficulties, and when the crossing has to be made in the vicinity of a flourishing port, where the banks are low-lying, the issue becomes more involved, because the rights of navigation must be respected. This was the case when it became necessary to carry one of the subsidiary Hill lines across the Willamette, a tributary of the Columbia River, near Portland (Oregon). The width of the river demanded a huge steel bridge, but as it

was impossible to elevate the structure sufficiently to enable large vessels to pass up-stream, a movable span had to be introduced. After the subject had been fully investigated it was felt that a swing bridge would meet the situation most effectively. The bridge itself measures 1,762 feet in length, and is divided into five spans carried upon massive masonry piers. The central is the draw-span, and in order to meet local requirements it was made the tremendous length of 521 feet, which renders it the largest of its type in the world.

In the construction of the narrow gauge electric railway from Bellegarde to Chézéry the most formidable obstacle was a deep rift in the Jura Mountains, through which runs the Valserine, a tributary of the Rhine. At the point of crossing the waterway flows between two towering walls, and the only means of spanning the gap was by means of a single masonry arch 267 feet in the



THE COMPLETED 267-FEET ARCH SPAN OF THE MONTANGAS MASONRY BRIDGE.
Showing the timber falsework under demolition.



THE WILLAMETTE BRIDGE ACROSS THE COLUMBIA RIVER. IT HAS THE LONGEST DRAW-SPAN (521 FEET) IN THE WORLD.

clear, bringing the rails 217 feet above the stream.

Monsieur Picard, engineer-in-chief of roads and bridges for the Ain Department, decided upon the single span masonry arch for this bridge owing to the intensely hard character of the rock forming the cliffs, and he decided to erect it by means of timber falsework. Three wooden towers were built from the bed of the stream to a height of 133 feet. They were of massive proportions in order to withstand the wind pressure and the enormous weight of the centering and masonry, as well as the swing of the water when the Valserine is in flood. To ensure the stability of these towers they were anchored to the cliff by means of steel guy ropes. Upon these towers was erected a maze of timbering forming the centering. This was a striking piece of work in itself which required no less than 21,000 feet of timber and 30 tons of iron and steel.

When the masonry had been set the timber work was demolished, and the method was as interesting as that of its erection. The various parts of the wooden framework rested on boxes of sand. When the stonework had been completed, the centering was dropped clear of the arch by allowing the sand to run out of the boxes. Then the intricate maze of timber was permitted to collapse into the ravine, where it was recovered. Whereas the erection of the elaborate wooden towers and centering for the Montangas Bridge, as it is called, had occupied four months, its demolition and removal occupied less than half that time.

Another important colonial bridge building undertaking in which the Americans succeeded was that which to-day carries the New South Wales Government line across the Hawkesbury River. It was a big enterprise of seven 416-foot spans, and in fact still ranks as the largest and most important work of this class in the Antipodes. At this point the estuary of the waterway is somewhat wide and deep, so

that the builders were confronted with a delicate task, which was not free from difficulty owing to the nature of the foundations.

The claims of navigation had to be re-

the masonry pier. The handling of such a huge cylinder, its manipulation when afloat, and sinking into position through the silt, offered the bridge builders a somewhat harassing duty. Exasperating mishaps,



By permission of the Agent-General for New South Wales.

A BRIDGE-BUILDING WONDER OF THE SOUTHERN HEMISPHERE.

The massive steel structure across the Hawkesbury River, New South Wales.

spected, and this demand necessitated the provision of a clearance of 40 feet at high water to permit the passage of river steamers and other small craft. The builders were confronted with a water-depth of 40 feet, strong tides, and, owing to the detritus brought down, about 100 or more feet of soft mud, which had to be penetrated before a sufficiently solid foundation could be obtained for the caissons carrying the masonry piers. In one case a steel cylinder 150 feet in height had to be sunk into position and filled with concrete to receive

delays, and other interruptions over which no control could be exercised served to enhance the arduousness of the undertaking, but finally all the caissons were sunk, filled with concrete, and the masonry piers completed.

Then the spans had to be taken in hand. Timber falsework being out of the question, the steel had to be set by the pontoon method. A float was anchored in a suitable cove, and on the deck of this craft a scaffolding corresponding in height to the distance between the top of the piers and the water

at low tide was erected. On this the steel was set and riveted up. When complete a fleet of tugs caught hold of the pontoon, and at the first favourable opportunity tugged the ungainly craft with its superimposed 1,000 tons load of steel out to the required position between two piers. When the ends of the girders were brought dead into position the pontoon was made fast, and, the tide being high, was held there while the water fell. Presently under the falling tide the ends of the girders came to rest on the piers, and, the scaffolding and pontoon dropping clear with the falling water, the craft ultimately was drawn away, leaving the span in position. Even this straightforward operation, however, was not free from its anxieties.

On one occasion a pontoon got adrift, fouled some rocks and went aground. As the tide fell the pontoon took a desperate list, and the engineers quite anticipated that the top-heavy mass of steel would go by the board. But fortune favoured them; the steel held to its scaffold despite the ominous cant; and the derelict was retrieved, to be anchored where required.

Owing to the rigid stipulations concerning grade and curvature which were imposed

**The
St. Lawrence
Bridge.**

when the Grand Trunk Pacific was plotted across Canada, very heavy and extensive bridging became necessary to span the yawning depressions and wide rivers which for the most part run at right angles to the location. The greatest work is that which is in course of erection across the River St. Lawrence, just below the city of Quebec. When finished it will rank as the longest cantilever bridge in the world, with a span of 1,800 feet. As is well known, the first attempt to bridge this noble river ended in disaster. Some 1,800 tons of steel had been set in position when the whole crumpled up and fell into the river, carrying with it the army of workmen, 74 of whom lost their lives.

On the western or prairie section of this

second transcontinental the most important structure is the Battle River viaduct, spanning the valley and river of that name. This spidery link of steel is no less than $1\frac{1}{4}$ miles in length, and at the highest part the rails are 185 feet above the floor of the basin. The steel trestles are supported upon massive concrete pedestals, and the structure was erected from the deck level by means of a traveller, by which the steel brought up in trucks was raised and lowered into position. Timber falsework was employed only in one instance—to set the span across the Battle River.

The building of this bridge was marred by one sad accident, which is recalled by a monument crowning a knoll within sight of the railway **Heroism at Battle River Viaduct.** The falsework of the span across the waterway was in progress, and as the river was in flood and swinging along at a furious pace, extreme care was necessary. Suddenly three men fell into the water, where they were quite helpless. A young Englishman forming one of the engineering staff was near by at the moment, and, hearing the cries of distress, jumped in, taking no heed of the wicked current and other dangers. Being a strong swimmer, he was able to get two men to the bank, but when he grabbed the third man both sank, while a Scotsman, who likewise was striving to extend assistance, also disappeared from sight. The bodies of the young Englishman and another were recovered, but the third corpse eluded discovery.

Nowadays, owing to the elaborate precautions observed, fatalities when bridge-building are few and far between. Now and again there is a mishap necessitating the revision of the pay-rolls, but bearing in mind the daring character of the work, and the dangers to which the bridge flies are exposed, not forgetting their individual intrepidity, even the largest undertakings are completed without a more exacting penalty than broken limbs and contusions.



HOW THE CHICAGO, MILWAUKEE AND PUGET SOUND RAILWAY MAKES ITS TORTUOUS WAY THROUGH THE BITTER ROOT MOUNTAINS OF MONTANA

Building a Transcontinental Railway in Record Time—II

THE STORY OF THE CHICAGO, MILWAUKEE AND PUGET SOUND RAILWAY, ITS LOW GRADES, AND MARVELS OF ENGINEERING



LEAVING the summit, the railway descends the western slope through the wild, broken, narrow, albeit picturesque Sixteen-mile Canyon. The pioneer road took the easiest path along the bank of Sixteen-mile Creek, clinging tenaciously to the waterway, and following it through its bewildering twists and turns, ignoring curvature and

banks, and with the metals only a few feet above the water. But the new line follows an easier course, from the traffic point of view, traversing a gallery hewn out of the solid rock here, swinging across a deep gulch by means of a lofty steel trestle there, and plunging through projecting crags. Construction was costly, involving heavy tunnelling and elaborate steel trestling, but it favours economical operation, inasmuch

as the banks are easy and the curves are open. Emerging from the gloomy gorge, the railway reaches Lombard, where the Missouri River is picked up once more. By the waterway the distance between Mobridge and Lombard is 1,000 miles, but by the new railway it is only 623 miles.

A bridge, 425 feet in length, comprising five plate girder spans each of 85 feet, supported on concrete piers, carries the line once more across the Missouri River, which even here, near its headwaters, is an imposing waterway. Shortly afterwards the line commences another rise to overcome the main range of the Rockies. This is the heaviest part of the road, the ascent being somewhat abrupt, the uniform grade through the Pipestone Valley to the crest of the continent being 1 in 50 for 20 miles. In order to reach an elevation of 6,350 feet the line ascends the eastern flanks of the towering barrier in a series of easy curves, and the summit is reached by a tunnel driven beneath the Pipestone Pass for 2,263 feet. This tunnel is as straight as an arrow, and when drilled was lined with timber, which subsequently gave way to concrete. The altitude of 6,350 feet which is notched upon the Continental Divide is the highest elevation to which the rails of this transcontinental are lifted between the Missouri River and the Pacific seaboard.

Emerging from the tunnel, the line commences the descent of the western slopes immediately—the down grade for 4 miles is uniform at 1 in 60—to gain Butte, the great mining centre of Montana. From this city another line, the Butte, Anaconda and Pacific Railway, runs westwards and the existence of this road prompted the new venture to seek running powers over its metals for 14 miles to Durant. The arrangement is not of a permanent character, but was concluded merely in order to enable through communication between Chicago and the Western Sea to be established with

all possible speed. In fact, surveys were run for an independent location through this 14 miles, and were accepted, but the successful bargaining with the existing line offered a means of deferring construction thereon to a later date. After leaving Durant, however, the line thence to the Pacific coast is of new construction.

Between Butte and Durant the railway follows the Silverbow River through the narrow, deep rugged canyon of that name, then it picks up the Deer Lodge River, and subsequently the Hell Gate River to Bonner. In reality these are one continuous waterway, but are known under the three foregoing distinctive names through the respective territories traversed. After leaving the Hell Gate River the line picks up and elings to the Missoula River until a point is gained offering a suitable passage through the Bitter Root range.

On this section some very heavy work was found to be unavoidable, more particularly between Durant and Missoula. When the Chicago, Milwaukee and Puget Sound Railway plotters entered this country they ran a route parallel with the Northern Pacific Railway. The latter, with its characteristic enterprise, directly the new transeontinental was launched, set about putting its road in order. The stretch of line between Durant and Missoula was in urgent need of overhauling, and revisions were carried out without delay. Consequently, it was found that the surveys of the new line collided with the proposed improvements upon the system in possession.

Thereupon the directing forces of the two great railways laid their heads together, and, although rivals, decided upon friendly joint action. Each demanded its individual road—no money was to be paid over from one to the other in respect of trackage rights, that is, for the use of the other's metals. Accordingly, they decided to lay the two individual tracks at several places side by side, so that the uncommon circum-

Through the Rockies.

The Bitter Root Mountains.

The Western Descent.

stance of two big systems and powerful rivals sharing a common road bed is presented. This friendly spirit of co-operation proved advantageous to both, as it enabled the cost of expensive work to be shared between them. At one point they had to take out 425,000 cubic yards of material in order to make a deep cutting to preserve the grade. On its own initiative the new line had to undertake heavy excavation work to maintain its position, a cutting near Hell Gate station, which is driven through solid rock, involving the removal by dynamite and steam shovel, of 524,000 cubic yards, while another similar work entailed the shifting of 460,000 cubic yards of spoil.

In coming down the Missoula River between Garrison and Missoula the meanderings of the waterway imposed a heavy tax upon the ingenuity of the engineers. In order to reduce bridging to the minimum, the engineers changed the course of the waterway at several points.

The Missoula River is followed to St. Regis, where the river of the same name debouches from the Bitter Root Mountains. As this

A Marvellous Loop.

range lay athwart the location, its negotiation offered many anxious moments, and the plotting of the line through this rocky barrier ranks as one of the finest pieces of surveying and railway building ever consummated upon the North American continent. The Bitter Roots are ragged, irregular and steep, and from foot to crest are garbed with a dense clothing of green timber, hiding impassable couloirs and deep gullies. The St. Regis River offers the natural pathway to their crests, and accordingly is followed with a grade of 1 in 125 for 17 miles. As the eastern slope rises somewhat sharply, the engineers found that a direct course would impose too heavy a rise, so they laid out a marvellous loop, causing the road to double upon itself. The outcome is, that whereas the present route to the summit

is a matter of 11 miles, the grade is only 1 in 58.8.

The ascent ends at the St. Paul Pass, where, at an elevation of 4,170 feet, the line pierces the mountain 1,000 feet below the crest. This tunnel, which carries the line from

The Crest Tunnel.

Montana into Idaho, constitutes the crowning effort of the engineers in what is generally regarded as a striking display of engineering prowess. It is set upon a tangent, and is 8,751 feet in length, while the metals rise at 1 in 500 from either portal to the centre. Boring was entrusted to the firm of Winston Brothers, who have consummated some notable railway building achievements on the American continent. When they essayed the task the question of getting up the timber for lining had to be solved, because the tunnel was taken in hand before the track had reached either portal. The problem was overcome by laying down a cable tramway 5,000 feet in length, wherewith all material was hauled to the working faces 1,000 feet above.

The rapidity with which this tunnel was driven was the most remarkable feature of the work. The usual methods were adopted—first a heading, then a benching, and finally full excavation. On the eastern face the rock-hogs averaged an advance of 174.9 feet for the heading, and of 170.9 feet for the full excavation per month, while on the western side the respective averages were 221.2 and 224.3 feet per month.

On the western slopes of the Bitter Roots the line describes a double loop, similar in character to that followed upon the eastern ascent, in order to gain the valley. As the range in reality comprises a close succession of hills, rather than a continuous ridge, the line, by following an ever-falling, winding, sinuous location from hill to hill, gains the lower level. For miles ahead the track may be seen glistening in the sun, the cut-banks, where the shoulders of flanks have been trimmed back, betraying

prominently the handiwork of the engineer in his toil to maintain the grade.

In the descent the loop comes at a point 4 miles beyond the tunnel, where the railway strikes across a deep rift known as Kelly Creek. Here a steel trestle viaduct, 850 feet in length, by 217 feet high in the centre, had to be erected. A temporary tramway was laid up the steep mountain-side to the site to facilitate the handling of the material. Erection was carried out by means of the overhead traveller, and by the time the rift was spanned 1,123 tons of steel had been set in position. The work on the western slope of this range was somewhat elaborate, because, in addition to numerous viaducts and temporary timber trestles, 17 short tunnels, varying from 200 feet to 1,600 feet in length, had to be driven within a distance of 21 miles, to preserve the continuously falling grade, which during the last 17 miles averages 1 in 58 to gain the North Fork of the St. Joe River.

As the mountains press hard upon the waterway, the latter is followed for 30 miles, traversing extremely fertile, low-lying benches and little prairies nestling under the towering walls of rock. Shortly after leaving this waterway another ascent commences through the state of Washington, the ultimate issue of which is the overcoming of the snowy barrier which frowns upon the Pacific seaboard—the Cascades. The going is extremely hard, as the outlying ramparts of the Sierras are severely broken, causing the engineer to resort to extensive side-hill excavation.

But before the mountains could be entered the railway had to swing across the Columbia River, just below Beverly, and this entailed the setting of a huge steel structure 2,740½ feet in length, together with two timber trestle approaches, one of which was 1,300 feet in length. The fickleness of this waterway demanded a

massive structure, with supporting piers upon unusually substantial lines. In summer the river rolls along as lazily as the Thames; but when it receives the contributions from hundreds of creeks in its upper reaches, which come to life upon the melting of the snows, it rises and tears along with the ferocity of a mill-race, bearing flotsam and jetsam of all descriptions, which have been collected among the mountains, upon its bosom.

The bridge was designed and constructed under the direct supervision of the company's bridge engineers, and the steel portion of the work comprises seventeen spans. Ten spans of the deck truss type are each 150 feet in length, four are similar spans of 216 feet, while there are two 80-foot deck girders, and one through truss span of 266½ feet, which is placed over the navigable channel of the waterway, with the rails 71 feet above low water, and 40 feet above high water. The piers were built upon the cofferdam principle, with the pumping plants installed upon scows which were moored in the waterway. They are constructed of concrete, and the height of those on either side of the navigable channel from bottom of foundations to the rail level is 102 feet. The steel itself was placed in position by means of timber falsework, the piles for which were set by floating drivers. The metallic portion was erected by an overhead traveller. By the time the bridge was completed 4,561 tons of steel had been worked into it.

The west bank of this noble river gained, the railway presses westward, threading the picturesque sylvan Kittitas Valley, and then, picking up the Yakima River, forces its way into the foothills of the Cascades as far as Easton, where mountain climbing again commences. This gigantic range is traversed by way of the Snoqualmie Pass, which, it will be recalled, is that favoured by the Northern Pacific

The Columbia River Bridge.

Climbing the Cascades.



FILLING TOPOGRAPHER'S GULCH, IN THE CASCADES.

Hydraulic giants were set to work to wash the soil down into the ravine below. Before a handful of earth was moved the engineers spent £12,000 laying down flumes together with machinery to operate the "hydraulickers."

on its way to the west, and the line overcomes the snow-clothed crests by means of a tunnel. At this point the rails of the new line touch an elevation of 3,010 feet.

to be spanned. It was decided to fill this hollow with an earthen embankment. In the hope of tearing down the requisite ballast more rapidly than was possible



ONE OF THE BIGGEST

As the engineers could not span Topographer's Gulch, in the Cascade Mountains, with a bridge, to carry the mountain sides with huge powerful water jets. In this way they formed

In the last lap to the coast some very remarkable development work had to be consummated, while, in order to hasten the task of construction, various and unusual devices were tested. At one point the line, after ploughing through the side of a huge hump, emerged upon a deep vale, the walls of which were almost precipitous. A gap 1,120 feet in length by 123 feet deep had

with the steam shovel, the builders evolved and erected an elaborate electric scraper, wherewith it was hoped that a continuous river of earth might be pulled down into the waiting trucks below. But the scraper did not fulfil expectations. Breakdowns occurred with galling frequency, and at last the huge machine was thrown upon one side to be broken up

In order to discharge the earth equally around the nose of the embankment, which was forced gradually across the depression from one side, another ingenious

side of the loop, thereby bringing them on to the return track. The "Merry-go-round," as it was nicknamed, certainly proved to be a conspicuous time-saver, and



FILLS ON RECORD.

Chicago, Milwaukee and Puget Sound Railway, they proceeded to fill in the rift by washing down the adjacent an embankment 200 feet at the base, by 282 feet high and 800 feet long.

device was contrived to save shunting of the ballast trucks. At the end of the dump a big, semicircular loop was laid, and, as it overhung the bank, it was supported by guys and ropes from a central post in the manner of a giant's stride. The loaded trucks were pushed up one side of the loop, emptied wherever desired, and the empties then carried round the other

the whole of the huge embankment was built by its aid, the loop and its supporting central post being pushed forward intermittently as the dump crept farther and farther out into the depression.

But possibly the most spectacular piece of work among these mountains was the crossing of what is known as Topographer's Gulch, in the Cascades. This is

merely a huge V-shaped cleft in the range, where the flanks of one hump run down sharply for 282 feet to meet the ascending similarly steep flank of the succeeding hump. But at the plotted rail level the location stakes of the grade were 800 feet apart through the air.

How was the gap to be spanned? Investigation and discussion revealed the possibility of throwing up a substantial neck of solid earth across that rift to lead from hump to hump.

The engineers advocated recourse to hydraulic sluicing, and a pumping plant was set up to drive the powerful jets of water from the monitors. Long wooden flumes, leading from the cuttings, were laid down the mountain sides to empty into the abyss. By the time these elaborate preparations had been completed £12,000 had been expended. Then the pumping plant was set in action. The terrific force of the large water jets striking the mountain, through which a deep cutting was to be driven to receive the metals, tore the soft earth and small stones away in continuous steady streams. When all the monitors were at work and attacked the wall of earth simultaneously, an avalanche of mud and debris was set in motion, and emptied into the ravine, where the tapered ridge of earth which the engineers required was gradually formed, and the artificial hill at last brought level with the cutting upon either side.

This transcontinental in reality possesses two Pacific terminals, although they are within a few miles of each other. They are Seattle and Tacoma respectively. While the former is an established port of considerable importance, the latter is growing rapidly, and cherishes aspirations of some day equalling, or even rivalling, its next-door neighbour. When the line was projected, Tacoma, jealous of its competitor, stretched out a welcome hand to

the project, and promised all assistance if the company would only place it on a level with Seattle. Consequently, neither one nor the other port is described as the seaboard terminus: they are both on an equal footing, and both are served with the same number of trains. The company does not dare to run one extra train into Seattle. Should it do so, wrath untold would be poured upon it by Tacoma. Similarly it must not give Tacoma the slightest advantage, or Seattle would swear revenge. Such is the friendly rivalry between the ports of Puget Sound. The delicate situation was met very neatly by providing a junction at Renton, where incoming trains divide, one portion running north to Seattle, and the other south to Tacoma. Similarly coming east, a train starts in two sections—one from each port—to be connected at the junction.

Once construction was commenced at both ends it went forward with a merry swing. All arrangements were completed carefully in advance, **Setting Up a Record.** so that there might be no delay.

To save time, many of the bridges and viaducts were erected temporarily in the first instance to permit the construction trains to get ahead. Some of the steel bridges were built upon wooden trestles, and the concrete piers erected later. Timber trestling was carried out extensively for the same reason, though other gangs were turned on to these directly the track-layers had passed, dumping around the woodwork and thereby transforming these structures into solid earthen embankments.

Track-laying was not held up to await completion of tunnels. Wherever the condition allowed, "shoofly," or temporary, lines were laid around them. They were of an extremely makeshift character, and were often laid upon grades running up to 1 in 25 or even less. In fact, when the track-layer started operations upon these sections, two or three engines were often

£12,000
Preliminary
Expenses

Rival
Terminals.

required to push it forward, owing to the steepness of the banks. When the tunnels were completed and the metals laid through them, connection was made with the main line and the "shoolies" were torn up.

By this system of working it was rendered possible to keep the track-layer going at full capacity once it started work. And at places the going was so favourable that sometimes as many as 4 miles of metals were laid between sunrise and sunset during the summer season. Altogether 1,400 miles of new railway were built, and a record in such huge works set up, because the last spike was driven in Hell Gate Canyon on April 1st, 1909. Cur-

ously enough, this event took place within $1\frac{1}{2}$ miles of the point where the two arms of the Northern Pacific were joined together twenty-six years before.

Within the thirty-six months £17,000,000 had been expended in driving 360,000 lineal yards of tunnelling, handling 60,000,000 cubic yards of material in making cuttings and piling up embankments, erecting 20 miles of bridges across impassable gulches and swiftly flowing rivers, and paving 1,400 miles of grade with 200,000 tons of 85-pound steel rails. The Chicago, Milwaukee and Puget Sound Railway was completed in record time—an average of nearly 4 miles per month!



WONDERFUL PLOTTING AMONG THE BITTER ROOT MOUNTAINS, MONTANA, TO PRESERVE THE EASY GRADE OF THE CHICAGO, MILWAUKEE AND PUGET SOUND RAILWAY.

The line twists and worms by trestle, tunnel, cutting and fill along the mountain flanks in a bewildering manner, to reappear upon the distant slopes.



Copyright photograph by F. E. Mackay, Battersea Park.

THE SOUTH EASTERN FOLKESTONE-BOULOGNE BOAT EXPRESS. DRAWN BY 4-4-0 LOCOMOTIVE, AND WITH LOAD OF 320 TONS, MAKING 50 MILES AN HOUR.

Famous Expresses—V

SOME BRITISH AND SOUTH AFRICAN "CRACK" TRAINS



THE railways serving the south-eastern corner of England do not reveal speeds comparable with the big trunk roads of the country, although, taken on the whole, the performances are better than may be supposed. The country traversed is severely undulating, the routes, cutting the hill ranges at right angles, abounding in stiff banks and sharp curves.

The South Eastern and Chatham Railways probably possess some of the worst switchbacking reaches of main line track in these islands. On the trunk road of

the South Eastern section the gradient is encountered 5 miles out of London. From the 5th to the 17th mile-post is a continuous rise, the first reach of 4 miles varying from 1 in 140 to 1 in 120. In the succeeding 4 miles comes a continuous fall of 1 in 150, followed immediately by another rise to the 23rd mile-post. Then comes a sudden long descent of 7 miles, comprising 2 miles of 1 in 144, and 5 miles of 1 in 122, terminating in a severely sharp curve into Tonbridge Junction. The easiest section upon the whole line is then entered—15 miles of practically level road to Headcorn, on which reach it may be men-

tioned the highest speeds are notched, this straight level stretch forming an excellent galloping ground. Another steady pull against the collar is encountered for 11 miles, ranging from 1 in 280 to 1 in 300, stiffening later to 1 in 266 for 3 miles into Westenhanger, whence there is a fall for 12 miles at 1 in 260 into Dover.

On the Hastings line the grades are every whit as heavy. Immediately after clearing Tonbridge station there is a ruling grade of 1 in 95 to 1 in 100 for 5 miles, followed by a switchback for another 5 miles. This gives way to a continuous fall of 1 in 100, tailing off to 1 in 400 and level track to the 20th mile-post, from which point a steady rise with reaches of 1 in 100 extends for 6 miles to Battle; thence a descent over 5 miles into Hastings.

Although the down traffic feels the effect of such heavy rising and falling, it is the up-trains which suffer most. Severe grades are accentuated by the sharpness of the curves, these being more detrimental to speed on the upward than on the downward runs. Yet the average speed of the express

trains ranges between 42 and 46 miles per hour. Pride of place is taken by the boat expresses, which constitute an important feature of this railway's traffic. The 76.46 miles between Charing Cross and Dover Town are reeled off by the 9.0 a.m. out of London in 95 minutes, giving an average of 48.3 miles per hour, the load behind the engine averaging 315 tons. The boat train, representing a dead load of 315 tons, which leaves Victoria at 10.55 a.m. covers the 78.29 miles to Dover Pier in 98 minutes, giving an average of 48 miles per hour. The 1.58 p.m. from Charing Cross for Folkestone makes the 70.73 miles with a train of 320 tons in 88 minutes, representing 48.3 miles per hour. This train includes three of the latest Pullman cars, each of which weighs 33 tons. Owing to the lighter load hauled—170 tons—the highest average speed, 51.5 miles per hour, is put up by the 4.30 p.m. boat train from Charing Cross to Dover Pier.

Curiously enough, however, the highest speed is notched by an excursion train running between Reading and Deal. This



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THE GREAT CENTRAL 12.15 P.M. DOWN MANCHESTER LUNCHEON-CAR EXPRESS.

train follows the old route through the Weald of Kent, the 46.9 miles between Red Hill and Ashford being virtually straight and level. On the up journey the descending Ashford bank is favourable, with the result that the train, representing 200 tons, is able to clip the distance in 52 minutes, giving an average of 53.2 miles per hour.

Taking the main line of the Chatham section there is a sharp pull at 1 in 61 for $\frac{1}{2}$

**The Chatham
Gradients.**

mile out of Victoria. Between the 3rd and 6th mile-posts there is a rise of 1 in 191, giving way to a descent, followed by $1\frac{1}{2}$ miles of 1 in 95 to the 13th mile. For the following 14 miles the road is of a give-and-take order, leading to a descent for 6 miles at 1 in 100, but the sharp curves militate against any display of speed. A pull against the collar of 3 miles at 1 in 132 gives way to an undulating road for 16 miles to Faversham. Here the main line bifurcates, one road running to Dover and the other to Ramsgate. On the Dover section 4 miles at 1 in 100 are followed by a descent for 6 miles at 1 in 132, with another rise for 9 miles, whence there is a continuous fall at 1 in 130 into Dover. So far as the Ramsgate or Kent coast section is concerned, this is somewhat easier, the most severe grade being 1 in 75 for 2 miles descending to Ramsgate Harbour.

So far as the expresses are concerned, here again the speeds average between 40

**The Kent
Coast
Expresses.**

and 49.2 miles per hour, the outbound trains showing slightly better pace. The down "Cliftonville" reels off the 73.71 miles between Victoria and Margate West in 90 minutes, giving an average of 49.3 miles per hour. As far as Faversham the train runs as 225 tons, but a slip at this point reduces it to 150 tons thence to Ramsgate. The "Granville," with a load of 250 tons, takes 88 minutes to cover the 72.28 non-stop between Victoria and Westgate, thereby showing an average of 49.2

miles per hour. The heaviest down-train, however, is the 5.10 p.m. "City" to Ramsgate, the weight of which averages 280 tons to Faversham, where a slip reduces it to 170 tons. The 74.5 miles between St. Paul's and Margate are covered in 92 minutes, giving an average of 48.2 miles. Grades being against the train upon the upward runs the averages fall slightly, the "Cliftonville" being the crack express. With 250 tons behind the engine the 73.9 miles between Margate and Victoria are covered in 91 minutes—48.7 miles per hour.

As mentioned elsewhere, among British railways pride of place in point of speed attained is held by the North Eastern Railway, **North Eastern Expresses.** which operates the fastest

flyer in the British Empire. While this particular express absorbs paramount attention there are many other trains upon the system which are worthy of attention, especially those running between London, Edinburgh, and other Scottish points, this railway constituting the middle partner in the East Coast route between London and Scotland. While officially the Great Northern Railway, which handles the first and last sections of the Scottish traffic—according to direction—has the termination of its metals at Shafthulme Junction, it has running powers over the succeeding 28 miles to York. From this point the North Eastern Railway extends to Berwick-on-Tweed, where junction is effected with the North British Railway, which continues the route to Edinburgh, Inverness, and other points.

The North Eastern, with which is amalgamated the first public railway—the historic Stockton and Darlington line which was opened for traffic in 1825—serves one of the most congested areas of England. Density of traffic therefore is only to be expected, and this in turn reacts upon high speed working. Despite this disadvantage, however, the Flying Scotsman in its run between York and the Border is able to notch some creditable speeds,



THE GREAT CENTRAL EXPRESS MAKING SPEED ON ITS NON-STOP RUN OF
164 $\frac{3}{4}$ MILES BETWEEN LONDON AND SHEFFIELD.

The locomotive belongs to the Sir Sam Fay (4-6-0) class, the largest and most powerful on the
Great Central system.

although the country traversed is considerably more rugged than that between King's Cross and York. The trains are run practically intact from end to end of the journey, the average load being some 300 tons.

In 1899 the three great lines which had shared the traffic flowing between the metropolis, the Midlands, and the North were threatened by a new competitor.

initiative. Passengers are being attracted by the latest expressions of travelling comfort and locomotive effort.

The most powerful locomotives engaged in this service are those of the Sir Sam Fay (4-6-0) class, which have already been described. The service of this type, however, is by no means confined to passenger exigencies, being used alike for fast goods and express fish transportation, the



FAST PASSENGER TRAIN ON THE 3 FEET 6 INCHES GAUGE OF THE SOUTH AFRICAN GOVERNMENT RAILWAYS.

This was the Great Central Railway. Prior to 1893 when the parliamentary Act authorising the extension to London was passed, this had been a cross-country system, under the title of the Manchester, Sheffield, and Lincolnshire Railway. In its development under this style it had thrown out its tentacles southwards until it reached Annesley, a few miles north of Nottingham. Thence to London was a matter of only 92 miles, and it is not surprising that the railway concluded that the closing of this gap would enable it to enhance its revenue and traffic, by tapping the metropolis.

The Great Central is developing into a serious competitor for the northern traffic. A bold bid for popular favour is being made by the display of enterprise and

latter constituting one of the outstanding features of the railway's operations. The longest non-stop run on the system is that between London and Sheffield, 164.75 miles.

Attention is drawn elsewhere to the outstanding engineering points of interest concerning the South African railways. As may be surmised from a perusal thereof, high speeds are impossible, owing to the severe differences in level which have to be overcome, and the sharp curves with which the lines abound. The "Orange Limited," running between Cape Town and Johannesburg, is probably the finest expression of long distance fast travelling which that country is able to offer. The distance between the two cities in question is 1,011 miles, and this is covered in $36\frac{1}{4}$ hours—an average of 27.8 miles per hour.

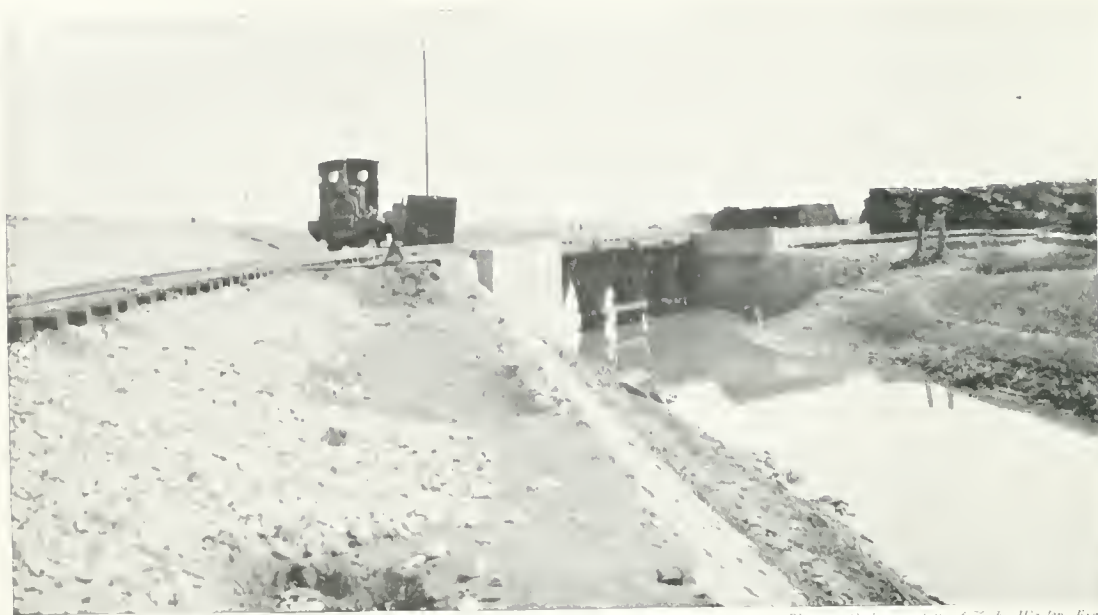


THE UP "FLYING SCOTSMAN" (10 A.M. EX EDINBURGH)



Photograph by permission of R. J. Purves, Esq.

CROSSING THE KING EDWARD BRIDGE, NEWCASTLE-ON-TYNE.

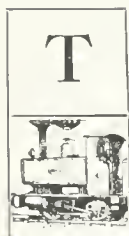


Photograph by courtesy of J. E. Waller, Esq.

BRIDGE OVER THE IRRIGATION CANAL AT FARSHUT JUNCTION.

Traversing the Libyan Desert

THE SURVEY AND CONSTRUCTION OF THE WESTERN OASES RAILWAY FROM
THE NILE TO KHARGEH



THE general impression prevails that the fertile stretches of modern Egypt are confined to the Nile Valley. This is a fallacy. By reference to the map of the territory the names of somewhat remote spots, such as Khargeh, Dakhla, Farafra and Baharia, will be observed in the north-western corner of the country. They seem so isolated as to be liable to dismissal as insignificant native settlements, cut off from civilisation on the East by the arid expanse of the Libyan Desert.

But, as a matter of fact, these little communities are remnants of what was once a flourishing land, known to-day as the Western Oases. Some 30,000 natives eke out an agricultural existence in a district rich in ruined temples and other

remains of bygone Empires. These evidences of Egyptian, Persian and Roman activity indicate only too palpably that in the remote past the surrounding country constituted a humming hive of industry. Accordingly, it is only natural to surmise that if the ancients were able to extract wealth from the territory, modern efforts under scientific conditions also should prove remunerative.

This opinion was entertained by certain perspicacious "Adventurers," who succeeded in obtaining a concession from the Egyptian Government to open up the Oases. But unfortunately there was one serious handicap. An 80-miles' stretch of uninviting sun-blistered expanse of sand, where siroccos vent their savage fury, separated them from the Nile Valley, constituting a formidable barrier to

trade intercommunication with civilisation. There was one way, and one way only, whereby the Oases might be reached. This was by camel train over the trails, extending from strategical points on the Nile to Khargeh and the adjacent settlements. The camel journey, however, was scarcely attractive. If the going were good, five days would see the distance covered; if severe sandstorms buffeted the camel-train, then a week or more might be expended on the trip. Moreover, one had to be prepared to suffer violent fluctuations in temperature during the twenty-four hours: adequate supplies of water had to be carried, because the desert does not yield a gill of liquid: while there was the risk of being accompanied by natives who, although they knew the way blindfolded, sometimes were possessed of reputations which, if known, scarcely would inspire confidence.

The concessionaires, as a preliminary, dispatched two mining engineers, Messrs.

The Preliminary Survey. Lake and Currie, to the Oases to report upon the possibilities of irrigation, because everything turned upon this issue. These

gentlemen experienced indescribable hardships, but eventually prepared a favourable report. But they emphasised the fact that nothing could be done unless the intervening stretch of desert were spanned by a railway. They related that the provision of such facilities would not present any great difficulty, except in the descent into the Oases, where, owing to the abrupt break-off of the plateau, a rack section appeared to be imperative. They pointed out that construction would not be costly, and even indicated, as a result of their rough reconnaissance, a feasible location. They suggested that the Egyptian State Railway system should be tapped at Farshut, some 340 miles south of Cairo, which virtually offered the point nearest the Oases, so that the length of the desert section might be reduced to the minimum.

The concessions eventually were taken up by a company formed for the purpose, the Corporation of Western Egypt. As no development of the Oases could be undertaken before the railway was laid, this was taken in hand without delay, Messrs. Kineaid, Waller, Manville and Dawson being appointed consulting engineers to the project, and Mr. J. Edward Waller, M.Inst.C.E., of the engineering firm in question, visited Egypt to make a personal study of the situation. He was accompanied by Mr. O. J. Shedlock, M.Inst.C.E., who acted as his first lieutenant, and the investigations of the mining engineers, Messrs. Lake and Currie, having emphasised Farshut as the most suitable starting-point for the line, the surveyors made this their headquarters, this point being reached on January 8th, 1905. A train of camels was made up, and Messrs. Waller and Shedlock moved off into the desert to spy out the route for the railway. In all preliminary surveys distances, as well as altitudes, are calculated approximately, pacing being the usual method for determining the former, and an aneroid barometer sufficing for the latter factor. On this occasion, however, Mr. Waller availed himself of the well-ascertained fact that the normal walking pace of the camel, when left to itself, is a steady two miles per hour. This may appear to be a somewhat haphazard method of taking distances, but it was considered to be sufficiently reliable for a flying survey, and in this particular instance it proved strikingly accurate.

While crossing the desert was free from untoward incident, considerable personal discomfort was experienced. At mid-day the heat of the sun was intense, the face and hands being blistered, but, at the same time, all parts of the body which were protected from the direct rays of the sun were chilled by the intensely cold dry wind which blew persistently from the north

Curious Climatic Conditions.

over miles and miles of rolling desert. Such a combination probably is rare, but the curious anomaly arose that, despite the great heat of the sun, the heaviest available clothing, which was only intended for use

convinced that somewhere or other there must be another and easier means of access, although the interrogation of the Omdah of Khargeh and other inhabitants to this end had been in vain. He maintained his



POOLS NEAR MEHERIG.

Photograph by courtesy of J. E. Waller, Esq.

This illustration shows the character of the country as the Oases are approached.

after sunset when intense cold prevailed, had to be donned. Even then the surveyors failed to keep warm, and at frequent intervals dismounted from their camels and trudged afoot to keep their blood in circulation.

Notwithstanding the climatic hardships which were encountered, the survey party moved with striking rapidity across the arid limestone plateau, the daily advance ranging between 18 and 22 miles. On the seventh day out of Farshut a camp was pitched for the purpose of reconnoitring the escarpment and the Sohag Pass, whence the line was to descend into the Oases. Mr. Waller had resolved to eliminate the rack section leading into the depression if there were the slenderest feasibility of so doing, and, accordingly, he probed the scarp for a considerable distance north and south of the usual camel trail. He was

opinion from the observance of rifts on the plateau, which lent colour to the supposition that these were the remains of long-dried-up streams and rivers, which in times gone by had emptied into the Oases.

This grim obstinacy and perseverance was rewarded. Selecting one rift which appeared particularly promising, and inwardly convinced that the vanished river had ploughed a course down the scarp somewhere or other, Mr. Waller dispatched the sheik in charge of the caravan to follow its devious track and discover if it would ultimately bring him into the Oases. The anticipation proved correct, and the sheik was able to indicate the point at which the ravine terminated in the Oases, the entrance being screened from observation by a sand dune of great size. This was sufficiently encouraging to prompt closer investigations, the up-

shot of which was the elimination of the rack section, which had been feared so much, in favour of a path which rendered possible a grade of 1 in 25. This, though somewhat steep, Mr. Waller did not consider to be a prohibitive incline, seeing that there are several railways in different parts of the world with even steeper banks worked by adhesion. Besides, it was quite possible, when the detailed surveys were undertaken, that the grade could be eased appreciably.

Satisfied with this discovery Mr. Waller proceeded to link up the new section with

decided to abandon the idea of linking the two lines at Farshut, and to carry the line across the Hod Samhud, a government irrigation embankment which at that time was under construction, if the authorities would undertake to widen the proposed work so as to receive the metals. This issue was settled amicably, and the point of interconnection established at a place now known as Khargeh Junction, a few miles north of Farshut.

While the two greatest problems had been adjusted satisfactorily—the starting point from the Nile Valley and the descent



WADI SAMHUD.

Photograph by courtesy of J. E. Waller, Esq.

A typical tract of country through which the railway passes.

the previously surveyed track across the plateau, which involved a considerable deviation. He then returned with his party to Farshut, which was regained on January 25th, the path-finding expedition having occupied fifteen days. At this juncture the question of connecting the projected Oases line with the Egyptian trunk road had to be settled. After exhaustive investigation Mr. Waller

into the Oases—there were many other detailed, though lesser, difficulties which still remained to be adjusted. The ascent from the Nile Valley to the desert plateau was fairly defined, but the plateau itself is not of that dead level character which might be supposed. At one point in particular considerable study was necessary to secure a line presenting a reasonably easy gradient without heavy earthworks.

The dunes also required close attention. These huge hills of sand, like the glaciers, are continually moving, although the progressive action across the country is unobservable to the naked eye. The heavy winds blowing upon the exposed side of the dune, pick up the sand therefrom, roll it over the crest, and then deposit it upon the sheltered side. As these dunes are of considerable proportions, Mr. Waller planned a route which left them well to one side.

In descending into the Oases, owing to the proposed location driving through a big sand bank, the engineer feared the possibility of subsequent accumulations blocking the line when constructed, but he prepared his plans in case such an untoward event should arise. He proposed sheds, similar to those utilised to protect railways against the movement of snow. Fortunately the gully has never been threatened, so that sand-shedding has not, so far at any rate, been found necessary.

Mr. Waller now returned to England, while Mr. Shedlock once more ventured upon the desert to complete more detailed, but still preliminary, surveys. Upon their completion Messrs. Kineaid, Waller, Manville and Dawson were in a position to advise the Corporation of Western Egypt that a railway was perfectly feasible, and could be carried out for a very low capital expenditure, and they recommended the adoption of the narrow gauge of 75 metre—2 feet 5½ inches—such as is used by the Egyptian Delta Railways, inasmuch as this would be adequate for many years to come, and would enable construction to be carried out for approximately one-half of the cost of a standard, or Stephenson, gauge road. They also advocated that construction should be carried out by direct labour, instead of letting the entire undertaking out to contract. By this means it would be possible to complete the railway in less time, and

at a lower cost. All the sub-letting that would be necessary would be in regard to the excavation and earthworks.

These proposals being accepted, construction was undertaken forthwith, even before the location surveys had been completed. The Corporation of Western Egypt appointed Mr. W. T. C. Beckett, M.Inst.C.E., general manager to carry out the local work to the requirements of the consulting engineers, while the latter in turn organised an engineering staff under Mr. Richard Knights, as resident engineer in charge, to complete the final surveys, alignment and levelling.

The engineering staff had an extremely trying experience upon the desert, being under canvas for some eight months. Sand storms harassed them severely, and at times the location pegs were obliterated.

The fact that every drop of water, as well as food, had to be brought up by camel transport enhanced the difficulties of the task, and movements had to be planned and carried out very carefully to maintain constant communication with the base. One day, while the party were in the field 25 miles from the depot, they were driven to shelter by a fierce downpour of rain which lasted for two hours. The natives were somewhat amazed at the occurrence, and stated that it was the first rain that had been seen in the district for nine years!

When the surveyors came to complete the location down the scarp they were able to improve slightly upon Mr.

Waller's rough preliminary by flattening the grade to 1 in 29. But when the latter revisited

the Oases in the following year to make a final run over the location, he devoted further attention to the descent into Khargeh with a view to finding even a still easier route. In this he was entirely successful, because he reduced the pull against the collar to 1 in 40. This revision

The Sand Peril.

A Nine Years' Drought.

Final Arrangements.

How the Descent was Secured.

was of incalculable importance, since the carrying capacity of a railway is limited by its ruling, or most adverse, gradient.

In order to secure this improvement the line had to be carried down the scarp in a kind of a corkscrew, sweeping curves and parallel tracks one above the other being

The permanent way is laid with steel rails, of Vignoles section, weighing 36 pounds per yard. For the most part steel sleepers are used, wood being employed in the Nile Valley and the Oases sections, as well as for a short distance near the 70th mile-post out of Khargeh Junction,



Photograph by courtesy of J. E. Waller, Esq.

A CAMEL TRANSPORT TRAIN DESCENDING THE WESTERN SCARP BY THE ZIG-ZAG ROAD.

By ingenious plotting the railway overcomes the obstacle with a maximum grade of 1 in 40.

laid. The ingenious plotting and building of the line at this point recalls the famous works of a similar character upon the Uganda and Hedjaz railways.

Meanwhile construction was being pushed ahead with all speed. The base of operations was established at Gara, where all materials and necessities were stored, and where adequate supplies of water were obtained by sinking a well. On the first sections out of the Nile Valley construction was comparatively easy owing to the prevailing level character of the limestone surface of the plateau, so that excavation and development was reduced to the minimum. When work was in full swing 3,500 natives found employment, and it demanded elaborate arrangements to keep such a large colony adequately supplied with water, which had to be hauled up in large tanks from Gara.

where a salt out-crop was encountered upon the desert. The line is provided throughout its length with a telephone. At mile intervals the posts are provided with plug holes to permit the circuit to be tapped by means of portable instruments carried on each train, whereby either terminus can be rung up for assistance in case of need, a derailment, or other mishap.

Owing to the absolute sterility of the desert there are no stations between Gara, in the Nile Valley, and Meherig, on the fringe of the Oases, a distance of $102\frac{3}{4}$ miles. Short sidings or loops are provided at intervals of 10 miles, to permit trains proceeding in opposite directions to pass.

At Khargeh Junction the rail level is 226 feet above the sea. Leaving Gara, the line crosses the Wadi Samhud to gain the Libyan Desert, the route being westerly.

The edge of the plateau is reached at mile 25 by means of a comparatively easy sustained grade of 1 in 50. The summit level is 1,265 feet above sea level. Then comes a gradual descent to the edge of the Oases, where the stiffest bank of 1 in 40 is encountered. The total length of the line is 122 miles, the desert stretch being 65 miles, while the descent into the Oases is effected in about 10 miles. At mile 57½, within a stone's throw of the line, an old Roman well was discovered, and, the water difficulty upon the plateau being acute, it was cleared out in the hope that it might be induced to yield supplies for the locomotives, but unfortunately anticipations were doomed to disappointment.

The locomotives were designed specially for the service, and are of the six-wheels coupled type, with 14-inch drivers. The cylinders are 14 inches in diameter with a stroke of 20 inches. The fire-box is of the Belpaire pattern. In order to protect the mechanism as much as possible from the fine penetrating sand all motion is enclosed. In running order the engine scales 22 tons. The tender, with ample capacity for coal and water, weighs about 13 tons laden, bringing the weight of the complete locomotive to 35 tons under service conditions. The rolling stock throughout is of the four-

wheel truck bogie type, and includes two water-tanks, each of 1,500 gallons capacity.

Bearing in mind the character of the country traversed, the railway was built for a very nominal figure—£200,000. This represents about £1,640 per mile. The cheapness of Sudanese labour contributed to this end very materially. The line is built substantially, and is a first-class narrow gauge road in every respect.

Shortly after completion the Western Oases Railway was taken over by the Government and incorporated with the Egyptian State system. The provision of the railway between this remote arable outpost of Egypt and the Nile Valley is already proving of incalculable value. It is inducing the natives to stay to till their land, whereas previously there was a persistent migration to the more congenial Nile Valley. Now that the Oases are in touch with the world's markets the land contiguous to the Nile holds out no inducements, because the soil in the Oases is equal, if not superior, to that fringing the River Nile in fertility. Indeed, many of the natives who left the Oases some years ago now are returning, so that the completion of this link of communication offers an interesting solution of the Egyptian land problem.



TREE AT HALF-WAY WELL.

Photograph by courtesy of J. E. Waller, Esq.

This old Roman well was opened up in the hope that it would yield a water supply, but it was found to be dry.



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THE CELILO BRIDGE CROSSING THE FALLS OF THAT NAME UPON THE COLUMBIA RIVER TO ENABLE THE OREGON TRUNK LINE TO ESTABLISH A CONNECTION WITH THE NORTH BANK ROAD.

On the north side of the waterway the bridge has a V approach.

A Fight for a Railway

THE SPIRITED STRUGGLE BETWEEN HILL AND HARRIMAN FOR THE DESCHUTES CANYON IN ORDER TO OPEN UP CENTRAL OREGON



IN the days when railways were young in Britain, extraordinary and varied were the tactics practised by competitive interests to secure strategical advantages over one another.

Spirited tussles were the order of the day, but as a rule no blood—only ink and words—was spilt. It is doubtful, even when tempers were raised to fever heat, whether such measures as attended the struggle of five or six years ago for a railway route into the hinterland of the

State of Oregon ever were contemplated, let alone practised.

It was a desperate fight between two great railway magnates—James J. Hill and Harriman. Each knew the measure of the other in matters pertaining to railway operation; each had control of unlimited finances to consummate his plans; each was in a position to command the services of the finest engineering ability necessary to complete the job in hand; and each was determined to win out. The result was that a country which had remained closed

for so many years suddenly found itself in the full glare of the limelight, discussed from one end of America to the other, and, what was more to the point, became provided with two first-class railways.

Central Oregon had occupied considerable attention for some years previously. It is

a richly fertile tract of 30,000 square miles, where agriculture

Hill v. Harriman. holds out every promise, and so was worthy of contest and conquest. Numerous projects for the railway invasion of this territory were mooted from time to time, but the expense of penetrating the district and the long length of unremunerative railway which would be unavoidable at the northern end proved an insurmountable stumbling-block.

Those interested in the development of this country naturally looked to "Jim" Hill for its salvation, but somehow or other these hopes failed to materialise. As a matter of fact the railway builder had his hands full at the time. He had ventured to carry his metals down the north bank of the Columbia River into Portland, and Harriman, who regarded this territory as his preserves, vigorously resented this advance. A long and bitter fight ensued between the two magnates, but Hill triumphed completely, because the courts routed Harriman's defence.

The penetration of the arable country of Central Oregon was difficult. There was,

Defunct Lines. in fact, only one available route, and that was by way of the Deschutes River, which for the latter part of its course, to join the Columbia, follows a meandering way between towering walls of rock, which at places press so closely together that the river becomes constricted and rushes through the canyon in turbulent rapids. Harriman had made an attempt to enter the country by striking off for 70 miles in a southerly direction from Biggs, a station on his road, which takes the southern bank of the Columbia River into Portland to Shaniko. Another small com-

pany had essayed a similar feat by running a line from Dalles, but they never got any farther than Dufur, 35 miles south. Both lines were virtually two streaks of rust. They not only ran through unproductive country, but, following the contour of the land in true pioneer fashion, were expensive to work. Harriman cherished ideas of pushing onwards from Shaniko, but his engineers dissuaded him, as it would not be worth the expense, and so the idea of opening up Central Oregon languished.

And the country might have waited for a railway still had it not been for a visitor who came into the country ostensibly bent upon an angling holiday. He was a persevering disciple of the Waltonian art, and followed the river from point to point, always fishing, fishing, fishing. He became quite a familiar figure to the old ranchers who had had the intrepidity to push in advance of civilisation, and was always a welcome guest in the homesteads at night. But fishing was his one obsession. When he had exhausted conversation concerning the river and its prizes, he fished in other directions. Did the ranchers want to realise and get out? Weren't they sick of waiting for a railway which never came? Why wasn't a railway run into it? What had become of the old charters granted in years gone by for railway construction?

The ranchers replied to all inquiries quite innocently. Yes, some would be glad to get into more congenial territory, only, having sunk their savings and unable to find buyers for their patches of land upon which they contrived to eke an existence, were forced to stay. Others held on because the right-of-way of the projected railway ran through their lands. Some of them even possessed such franchises, which either had been given to them by disgusted concessionaires, or had been purchased in the hope that some day they would become valuable.

The fisherman listened, sympathised with the old pioneers upon their ill-luck, and

A Mysterious Visitor.

then turned philanthropist. He would help them. Money was no object to him. He could make it easier than they could. Consequently, when the holiday drew to a close, the angler found himself possessed of a pile of papers entitling him to this and that ranch and something else. He appeared to be perfectly satisfied with his jaunt, and the old ranchers who went away with his dollars in their pockets were more than pleased at having got out of bad deals so profitably. The stranger returned to Portland, where he met a friend. The papers which had been exchanged for coin of the realm were examined, and, upon the conclusion of the conversation, the angler parted with his acquisitions for a round £30,000.

But the ranchers, as they went out, talked about the mysterious stranger who had spent weeks in their country,

A Clever Scheme.

had passed evenings with them,

and was mad enough to buy up their worthless properties. Many laughed, but others shook their heads, and expressed the conviction that there was method in the stranger's madness; that he had not visited such a hole as the Deschutes Canyon for his health; and that he had ulterior motives. Investigations revealed the fact that a controlling interest in the moribund Oregon Trunk Line Railway had been secured, together with rights of way through the Deschutes Canyon. Evidently something was afoot in the railway building game. The question was: "Who is behind it?" Upon this issue nothing satisfactory was obtainable. The whole scheme had been worked so skilfully that the stranger had disappeared without leaving a trace behind him.

Shortly afterwards a railway builder, under the guise of the Oregon Construction and Organisation Company, appeared at the mouth of the Deschutes River. Harriman's suspicions of the matter were confirmed. The chances were a thousand to one that

this Construction Company was acting on behalf of Jim Hill, because the man with the reins, Mr. Johnston Porter, had been identified with the march down the north bank of the Columbia.

Meantime Harriman had been working quietly, so as to be ready for any move directly a card was played. Unostentatiously he had engaged the

Harriman Moves.

services of George W. Boschke, one of the cleverest engineers in the States, and had told him to get ahead on a survey through the canyon. They covered their tracks well. They started out from Shaniko, an isolated, dreary spot in the heart of the arid belt, and by so doing were able to keep out inquisitive strangers. Everyone not connected with the party was scrutinised before he boarded the train at Biggs, and if deemed unsatisfactory was told that the train service had been suspended, that if he was so keen upon getting to such a hole as Shaniko, well, he could walk. It was an exhilarating though monotonous journey over 40 miles of desert!

The Harriman surveyors ran their lines up and down the river, but found that the superior side, from the construction point of view, was filed in the moribund charter. So they contented themselves with the opposite side of the waterway. The old Oregon charter was for a line as far as Madras. Forthwith, Harriman, when he filed his plans for a charter, decided upon Madras also. He called his project the "Deschutes Railroad," and filed his route according to law.

Then the battle commenced in grim earnest. No quarter was to be asked or given; neither would help the other; would not even oblige

The Fight Begins.

with a quid of tobacco. A polyglot crowd of navvies—Greeks, Italians, Montenegrins, Croats and what not—were recruited and rushed to the respective fronts. Shaniko became the headquarters of the Harriman campaign, whence all

supplies were shipped in. At first the navvies had to walk from Shaniko to the camps, and many by the time they reached the scene of action were too exhausted to do any work for days. Pack trains were organised with all speed to

The Hill forces had an equally titanic task on their side. For this work they pressed into service the privately-owned 35 miles of line running from Dalles to Dufur. Thence tôte-roads were driven to various points. Getting into the canyon



Photograph Copyright 1911 by Kiser Photo Co. for the Northern Pacific Railway.

THE HILL LINE THROUGH THE DESCHUTES CANYON.

Hill and Harriman disputed the way through the Deschutes Canyon to penetrate Central Oregon. The result is that the Hill line shown in the picture follows the one and the Harriman road the other side of the river.

carry in the explosives, foodstuffs, and other fairly easily portable supplies, while gangs of men were turned on to drive a rough wagon road to the various camps. It was merely a tôte-road, and the frenzied passage of steam shovels, ballast trucks, and light engines tore it up badly, but the £20,000 expended upon this preliminary was laid out to good purpose, because thereby over £200,000 worth of equipment and supplies were got into the construction camps.

proved a heart-breaking task, as the cliffs sheered up for a matter of 2,000 feet above the water. First, a narrow zig-zag trail was driven down the cliff face to facilitate the descent of the pack trains. Later, the trail was widened out to permit wheeled vehicles to move up and down, and these were manipulated by rope and tackle, the zig-zag being far too stiff to enable horses to move their loads unaided.

The fight for the possession of the requisite territory was strenuous, and it

was no mere paper or legal manœuvring to secure tactical advantages. Hand-to-hand fights between the opposing gangs were of frequent occurrence. The Hill navvies were in possession of a certain spot; the Harriman gangs coveted the territory,

up unobserved with lengths of fuse, and planting them successfully, fired them. The triumphant victors, detecting the sputtering lengths of fuse, and surmising that charges had been laid, rushed off in confusion to avoid, as they thought, being



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BUILDING THE ARCH SPAN OF THE CROOKED RIVER BRIDGE FROM BOTH SIDES OF THE CANYON SIMULTANEOUSLY, SHOWING THE TWO TRAVELLERS.

and the settlement of the issue was left to brute force. Positions were rushed and carried by overwhelming numbers, armed with pickaxes, spades, crowbars, hammers, and what-not. In turn, the visitors were dispossessed by stratagem. On one occasion the navvies had beat a hurried retreat under a rain of boulders from the heights above, launched by their adversaries, but the latter, when they entered into possession of the evacuated point, rushed off in a *sauf qui peut*. One or two of the dispossessed gang had stolen

blown sky-high, so that the vanquished were able to regain and to strengthen their position.

The sheriffs had the most harassing time of their lives. Johnston Porter, the head of the Hill constructional army, proved to be exceptionally elusive. This railway builder, accustomed to Western methods and country, and enjoying the tussle, got the law on his track very quickly. He had to lay out a round 100 miles of tête-roads, and at places where he found the public high roads to conflict with his plans, he unhesi-

tatingly diverted, or even closed, them to secure his purpose. Such high-handed disrespect of the rights of the people had its inevitable corollary. Injunctions were issued, and the sheriff was ordered to serve them upon Porter, but although the myrmidon of the law scoured the country for weeks, he never tracked the railway builder down until it was too late. Directly Porter had achieved his purpose, he restored or re-opened the highways, so that the injunction writ became useless.

On one occasion an effort was made to press the waterway into service. A large raft was built as an experiment and half a dozen men boarded her. A rope was passed to the bank to enable another gang to assist in steering the craft. But the argo, with its load, had not gone many hundred yards when it was caught in one of the fearful whirlpools, twisted round, wrenched to pieces, and sent drifting down-stream a mass of dismembered logs. Everything on board was lost, and the crew had an exciting scramble in the seething waters, one man failing to extricate himself.

Although Hill, by being first in the field, secured choice of route, and carried his surveys well forward, he received

**Hill
Checked.**

a severe check from his antagonist, who was building his line frenziedly down the opposite bank of the canyon. The Hill line had to swing across the river, but one obdurate rancher stood directly in the Hill right-of-way. Money could not induce him to sell out. A suit was brought against him to contest the validity of his rights. But before the action started the rancher had complied with the requirements of the law, and could not be dispossessed by any manner of means. Before the Hill forces realised the import of this move they found their obstruction assume a worse significance. The man sold his ranch to Harriman! Physical efforts at dispossession at once ensued, and constructional progress was held up because of the contests with fisti-

cuffs, tools, pieces of rock and other convenient missiles which were waged between the gangs of the two camps. Neither would give way, and matters remained in abeyance until the issue was settled by the two opposing factions making the land in dispute a joint right-of-way, and so the two lines were laid side by side.

The Deschutes River rises in the heights of the Cascade Mountains, 224 miles south of the Columbia. It flows in a northerly direction parallel with the impressive mountain range which frowns down upon the Pacific seaboard. In its upper reaches the waterway traverses exceedingly fertile highlands, where the benches lend themselves to the cultivation of varied produce. There are about 9,000 square miles of farming land immediately tributary to the river, and this territory is freely watered by numerous smaller streams rising on either side of the Deschutes River, which, after meandering through abrupt valleys and rolling bench-lands, finally empty into the first-named waterway. The principal tributary is the Crooked River, which winds and twists in a north-westerly direction through a first-class stock- and fruit-raising district.

**The
Deschutes
River.**

After flowing placidly for 35 miles through the arable country, the Deschutes pierces the mountain range which hems in the hinterland upon the northern side. The transformation is remarkably startling. Verdant rich soil rolling gently upwards towards the mountain ranges gives way to sterility. The river has only one possible outlet—the Deschutes Canyon—which is nothing more or less than a fissure in the rampart. For the last 140 miles of its northward flow the waterway surges, boils and thunders through this picturesque and impressive canyon, the cliffs of which at places rear up almost perpendicularly, and press so closely together that the river appears to be turned upon its side, and is nothing but a stretch of madly boiling

foam rushing forwards with fiendish velocity and absolutely unnavigable.

The Hill line runs through the canyon along one bank, while the Harriman road follows the opposite shore. The cost of construction rose to a huge figure owing to the enormous demand upon explosives in blasting two shelves a few feet above high water to receive the rails. The Hill system, realising the importance and wealth of the traffic which would ensue directly the territory was opened, set out to build a standard line in the beginning with easy grades and open curves, and laying the permanent way with 85-pound rails. The Harriman engineers cherished similar ambitions, but both found it a somewhat exasperating proposition, inasmuch as the metals had to be lifted to an altitude of 4,500 feet.

At one point the location of the Oregon Trunk Railway was interrupted by the Crooked River and its gulch. The latter is merely a crack in the earth's face, over 300 feet deep, with walls almost as vertical as a plummet. To avoid this canyon proved impossible, so the engineers boldly advocated a bridge. A single arch span of 340 feet, with the rails 320 feet above the floor of the rift, was designed. It was built out from each cliff upon the cantilever system, huge notches being cut in the edges of the precipitous walls to receive the skewbacks.

A unique feature in connection with this work were the means provided to enable the men to pass to and from their work. The camp had to be established in the canyon to secure the indispensable close proximity to water. An incline railway between the floor of the gulch and the top of the walls being impossible, a rope ladder was slung down one cliff, which the men were compelled to swarm up and down. The ladder was about 300 feet in length,



HOW THE "FLIES" WHO BUILT THE CROOKED RIVER CANYON BRIDGE REACHED THEIR WORK. A rope ladder was slung over the cliff communicating with the camp below.





SETTING THE LAST PIECE OF STEEL TO COMPLETE THE CROOKED RIVER CANYON BRIDGE.

The arch has a span of 340 feet, while the rails are 320 feet above the water. A cableway was thrown across the gorge for the transport of material.



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THE "HORSE-SHOE" IN THE DESCHUTES CANYON.

The Oregon Trunk line, built by J. J. Hill, taking the left bank, sweeps right round the curve, while the Harriman road, on the opposite bank, tunnels through the neck of the tongue as shown by the dotted line.

and some 400 rungs had to be negotiated. When a strong wind was howling through the rift, which acted as a funnel, climbing proved no easy task, as the ladder swung to and fro in the most disconcerting manner.

Upon emergence from the mouth of the Deschutes Canyon the Oregon Trunk Railway has to cross the Columbia River in order to effect a junction with the Spokane, Portland and Seattle Railway, or, as it is more colloquially called, the "North Bank Road." Some difficulty was experienced in determining the most suitable site for the crossing owing to the width and turbulent character of the Columbia River at this point, but ultimately it was decided to take it directly over the Celilo Falls, called upon their discovery in 1805, by Lewis and Clark, the famous explorers, the Great Falls of the Columbia. At this spot the river is 3,500 feet wide, so that an imposing and costly bridge was inevitable.

From end to end the structure measures 4,197.17 feet in length. It is a single-track bridge built entirely of steel, resting upon 29 piers and 3 abutments of concrete and granite. The river itself is crossed by means of seven through truss spans, the longest of which, over the main channel of the Columbia where it breaks over the Falls, being 316½ feet in length. An outstanding feature of the bridge is the bifurcated approach upon the Washington, or north, side of the waterway, to effect junctions with the "North Bank Road." The provision of this "Y" greatly facilitates the operation of the trains, those proceeding to and from Portland taking the western leg, while traffic to and from Spokane follows the eastern leg of the bifurcation. The approach spans are of the plate girder deck type. Leaving the Washington shore the track rises 25 feet to the mile in crossing the waterway, so that on the Oregon bank the metals are 100 feet above low, and 50 feet above high, water respectively.

A remarkable circumstance in connection with the location of this bridge is that the foundations rest on solid rock, which is entirely exposed during the season of low water which generally extends from September 1st to March 1st. During the remainder of the year the water rushes over these rocks with terrific fury, setting up fiendish rapids and whirlpools. Under these conditions the period available for work upon the foundations of the piers was somewhat restricted, the men being crowded upon the sites during the low water season so that the utmost advance might be effected before the river rose, because when in flood the piers were absolutely unapproachable. For a similar reason it was absolutely impracticable to carry out the setting of the steel by means of timber falsework. The longest span, immediately over the main channel and the Falls, was erected cantilever fashion. In the erection of the piers 18,000 cubic yards of concrete and 155,000 pounds of steel reinforcing bars were used. The setting of the steel was started on May 11th, 1911, and was completed on December 19th of the same year.

The first section of the Oregon Trunk line was from the Dalles to Madras, a distance of 10 miles. Directly work was commenced upon this section it was decided to carry it to Bend, 40 miles beyond, so as to reach the heart of the new territory. This is as far as the line has been carried at present, but charters have been secured, and surveys run, for its extension almost due south through the Crater Lake National Park to Klamath and Butte Falls, whence a railway runs to Medford on the Southern Pacific system. Ultimately the line will be extended southwards to Sacramento and San Francisco, thereby providing the section of the vast rail network of lines in Washington with direct and independent connection with San Francisco.

**Difficult
Bridge-
Building.**

**Crossing
the Columbia
River.**

**Future
Extension.**

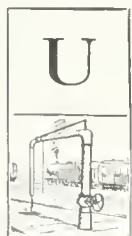


THE BUCYRUS SELF-CONTAINED, SELF-PROPELLING PILE-DRIVER AT WORK UPON THE AMERICAN DESERT.

The rear vehicle carries the water and fuel supplies

The Railway Builders' Heavy Artillery—III

BALLAST LEVELLERS, PILE-DRIVERS AND MECHANICAL BRIDGE-BUILDERS



UPON some railways the task of unloading and levelling is accomplished in one operation. The spoil discharged on either or both sides of the track simultaneously forms a ridge. For levelling purposes an additional car is attached to the rear of the train, and behind the plough car. This vehicle carries a substantial heavy structure supporting a wing projecting from one or

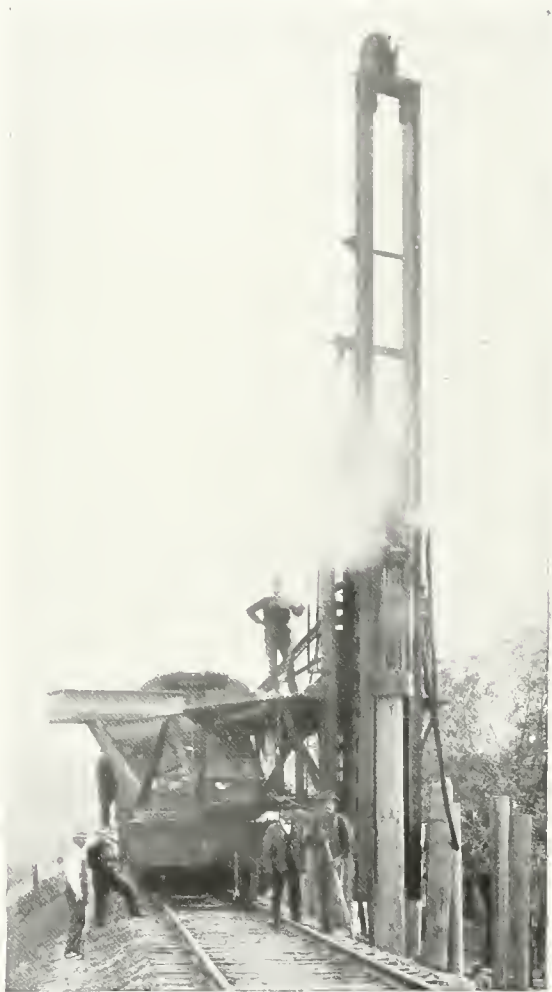
both sides of the train, and set to the requisite height above the ground. The unloader is started up first, and after it has completed about half its work, the train moves slowly forward, thereby bringing the leveller at the rear into action. As the train advances the leveller, coming into contact with the ridge of discharged spoil, spreads the latter out, leaving it with a smooth level surface. This time-saving system is especially useful in connection

with final ballasting, after the track has been laid, lifted and levelled, or when it is desired to re-ballast the permanent way outside the metals.

For ballasting and levelling between a pair of metals—the “four-foot” way—a different system is adopted. In this case, as the spoil has to be discharged between the metals, a hopper wagon with bottom opening doors is employed. These vehicles will carry up to 50 cubic yards of ballast, and the doors are opened by a lever or other suitable quick-acting device. The whole of the contents is then discharged in a ridge in the four-foot way. To level it down an enlarged edition of a scoop ballaster is used. This is a flat deck truck carrying a pedestal, similar to a gun-mounting, in the centre, and fitted with a hand wheel. Below the truck frame is a double scoop set at an angle to the front of the car, and with its apex in the centre line of the track. Each scoop is of sufficient length to over-reach the rail on either side. By means of the hand wheel above it can be raised or lowered to any desired height. After the hopper wagons have dumped their loads in the four-foot way, which is done while the train is stationary, the levelling plough attached to the rear of the train is adjusted, the train then moves slowly forward, and the scoops at once level the ridge of ballast deposited a few minutes previously.

The unloader has proved itself highly useful in another phase of railway building operations. This is for throwing the track, i.e. moving a line bodily, and intact with sleepers, some distance to one side. For instance, the Grand Trunk Railway of Canada was overhauling its main line to the west of Port Huron. At one point, in order to eliminate a bank, a new cutting was driven 15 feet away from, and 10 feet below, the old track. One set of metals was laid upon the new stretch of permanent way, but the second road was moved laterally from its previous position. This was ac-

complished as follows: The unloader and a second deck car were attached to the locomotive. The end of the cable was taken off the drum, passed round an improvised sheave at the front end of the second wagon, and then at right angles to



FRONT VIEW OF BUCYRUS PILE-DRIVER, SHOWING STEAM HAMMER AND SLEWING MOTION.

be hooked to the old set of rails. In order to prevent the latter kinking at the point where the hook was attached, a 10 feet length of old rail was laid inside the near rail, the cable being attached to both. The rope then was wound in, pulling the track spiked to the sleepers with it. The track was moved sideways about 15 feet, and dropped about 10 feet, and was pulled into the desired position upon the new grade, so

that subsequent work was confined to trueing-up, levelling, and ballasting. The old track was not severed at certain intervals so as to be moved in complete sections and then rejoined, but was moved just as it was laid, the average length of line moved with each haul being about 100 feet. The task was achieved quite as effectively by this means as if shifting had been carried out by hand labour, and 75 per cent. cheaper. Under the latter conditions the men had not been able to move more than a mile of line in a single whole working day, and then the cost averaged £37 per mile. By mechanical operation with the unloader the cost of the work was reduced to about £8 10s. per mile, and was completed in less than 8 hours. Such a difference in time and cost represents a vital factor in big railway-building operations.

In those countries where extensive resort is made to timber trestling, either as temporary or permanent measures of construction, the setting of the vertical members of the bents makes a pronounced demand upon power. The pile-driver of the early days was a primitive and often extemporised contrivance, but in these high-pressure times more business-like, powerful, economical, and rapid methods are essential.

The mechanical pile-driver, relatively speaking, is a modern implement, but at the same time it is one of the most useful. In common with other tools, it has undergone considerable development to widen its field of application and range of action. In its latest and most utilitarian form it is a somewhat elaborate apparatus capable of furnishing power not only for the operation of the tool, but to render it independent of locomotive effort in moving from point to point. And not only is it furnished with powerful mechanism for self-propulsion, but is capable of drawing two or three trucks containing material used in its work at a speed up to 20 miles an hour over average

grades and curves. Thus it is virtually a complete train in itself.

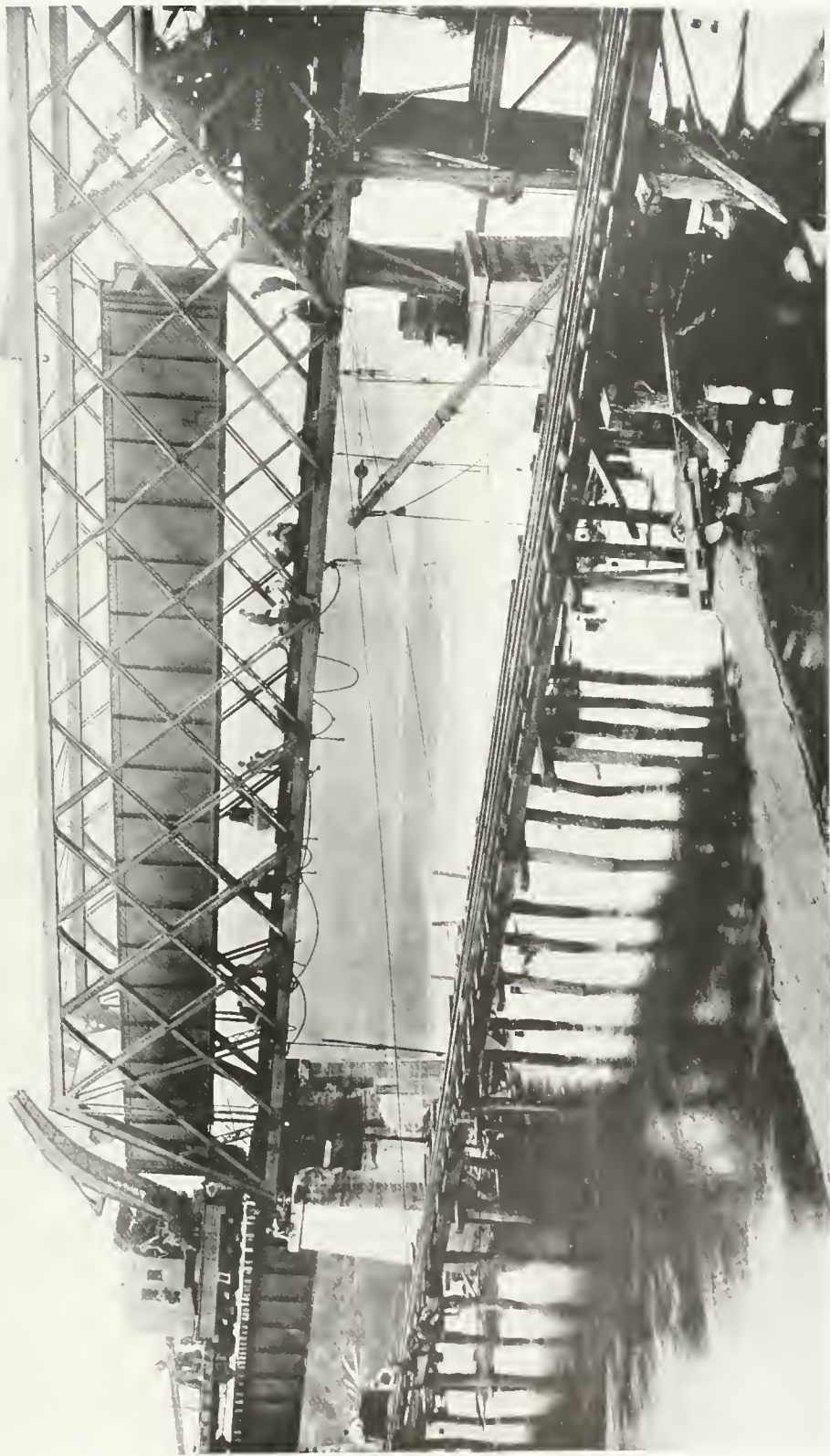
The machine is built upon a two four-wheeled truck deck car of standard dimensions. At the rear end of the truck a cab contains the self-propelling mechanism and the gear for operating the pile-driver. The forward end of the truck carries a solid pedestal, upon which is pivoted the truss carrying the driver, and upon which the latter is nested in a horizontal position when travelling. The truss is pivotally mounted to enable the driver to be swung out and operated on either side of the track, the overhang being sufficient to enable piles to be driven a distance of 20 feet or so from the centre line of the track. The rear end of the truss itself is furnished with a counterweight. The leader, when raised at the forward end, which is likewise built of steel, gives a drop up to some 50 feet. Either drop or a steam hammer can be used for driving purposes, the latter being most generally favoured in the largest and most powerful implements, as it is quicker to operate.

Owing to the necessity of driving piles at an angle—such as the outer members of a bent—arrangements are provided whereby the leader can be set to the angle required for the pile, the maximum degree of inclination coinciding with that required in railway practice. The mobility of the tool is an outstanding feature, inasmuch as it enables work to be undertaken without interference to traffic, which in the case of single tracks is a decided advantage, the driver being able to move to the nearest siding to permit trains to pass. These machines are of great strength, while simplicity of manipulation and quickness in operation have been responsible for their widespread adoption upon those lines where a considerable amount of trestle-work has to be maintained.

In a previous chapter the powerful cranes which have been evolved for wrecking pur-

**A
Mechanical
Pile-driver.**

**Strength
with
Simplicity.**



REBUILDING A BRIDGE BY MEANS OF INDUSTRIAL WORKS WRECKING CRANES.

These powerful machines are well adapted to such heavy work, and have contributed very materially to that rapid replacement of bridges which is a conspicuous feature of modern railway engineering

poses were described. But although the removal of debris in the minimum of time constitutes the paramount work of these machines, it by no means represents their complete sphere of utility. There are many

conditions, except in those instances where this practice is absolutely impossible. While Sunday, owing to traffic being at its lowest ebb, constitutes an ideal day for such work, the latter also has to be carried



AN INDUSTRIAL WORKS WRECKING CRANE ADAPTED TO HANDLE AN AWKWARD LOAD.

An extemporised boom attached to the crane-jib enabled this machine to place unaided an 80-foot girder weighing 20 tons.

other duties which can be carried out very efficiently by the wrecking crane owing to its enormous lifting power. The renewal of bridges is a conspicuous branch of such work. This is particularly noticeable in the United States. During the past few years the western roads have been spending millions to bring their tracks into line with modern practice in order to secure higher speeds and to permit the movement of heavier loads and locomotives. When the railways were built originally, timber was used almost exclusively for bridges. Such structures are impossible under modern conditions, so they are being torn out to be replaced in steel.

It is imperative, however, that such work should be consummated under traffic con-

on during other days, and often a complete replacement of a span has to take place between the passing of two trains.

In considering the problem, the bridge engineers concluded that the wrecking cranes could be adapted very easily and efficiently to such work. The first attempts proving completely successful, this implement is used almost exclusively for such work to-day, except in the largest bridges, and the transformation is effected with a marked economy in constructional costs.

The general practice is to erect the piers to the required level beneath the existing structure. The steel spans are set up at a convenient point near the bridge, and, when all is ready, the wrecking cranes are brought up. The old bridge is then lifted

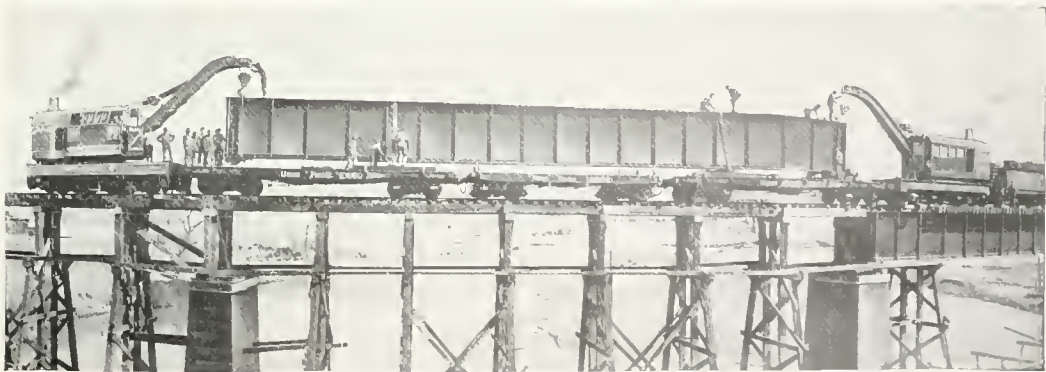
bodily by a crane at each end—if there are several spans, each is handled separately—and swung to one side, generally upon waiting trucks, and hauled out of the way without delay. The new span is then brought up and, grasped at each end by a crane, is lifted bodily to be lowered into position. Owing to the main hoist and auxiliary brake for handling loads being so efficient, large and heavy units of structural steel may be handled in this manner, and may be set in position with absolute accuracy and without the slightest jolt or jar.

Realising the possibilities of the wrecking crane in this particular field, the Industrial Works, of Bay City, Michigan, who have specialised in this class of tool, have devoted special attention to its adaptability to bridge erection. The jib of the wrecking crane is short, in order to secure the maximum lifting effort, and because an overhang in wrecking operations is not essential. For bridge work, however, a longer jib often is required, and this may be achieved by attaching an improvised extension boom to the existing jib. In this way the radius of working is appreciably extended. In one instance the hoisting and placing of an 80-foot plate girder, weighing 20 tons, was carried out there-

with. In order to obtain the necessary stability to the crane when lifting such a load at right angles to the car, an outrigger system is employed. This consists of beams which are mounted under each end of the ear body, and which, by means of a ratchet system, are extended to a distance of 4 feet on either side of the ear.

Although the improvised jib extension meets the situation very effectively, the designers of this type of crane realised that generally speaking special equipment was necessary, particularly in connection with the boom. Accordingly they designed a special type of boom, whereby the radius of action is increased considerably, both horizontally and vertically. This can be attached to any type of crane made by this firm, regardless of size and capacity, and has proved exceptionally useful in settling bridge spans from a low temporary track laid alongside.

This utilisation of the wrecking crane represents one of the latest developments in railway engineering, but it is one which the bridge engineer has come to appreciate. In many cases it dispenses with the necessity to erect falsework, while, what is far more vital from the railway's point of view, the time and cost in replacing a structure is reduced very considerably.



HOW WRECKING CRANES LOWER INTO POSITION A MASSIVE PLATE GIRDER.



Photograph supplied by the South African Railways.

CANTILEVER BRIDGE SPANNING THE GOURITZ RIVER, NEAR MOSSIE BAY.

The Railway Network of South Africa—II

HOW THE STATE GOVERNMENTS ACQUIRED AND DEVELOPED THEIR RAILWAYS

WHEN it was decided to continue the line from the capital towards the Transvaal boundary the engineers found themselves faced with the most difficult stretch of the whole country, because the Biggarsberg and Drakensberg ranges, which run at right angles to the location, had to be overcome. Shortly after leaving Pietermaritzburg the line crosses the 3,000 feet altitude mark, and does not descend below that



level again. The first summit is reached at Highlands, where an altitude of 5,152 feet above sea level is notched, no less than 3,098 feet being overcome in a distance of about 60 miles.

After crossing the summit the line descends abruptly at 1 in 50, the total descent being 1,121 feet in 15½ miles. This is considered to be one of the worst stretches upon the whole of the main line, particularly as the ascent is adverse to the heaviest traffic—the movement of coal to

coastal points. As this mineral constitutes the principal item in transportation, there is a heavy struggle up the bank between Estecourt and the summit. The coal trains invariably comprise twelve or more heavy iron trucks, and helpers have to be maintained at Estecourt to lift them over the hump. Three Mallets, as a rule, are required to perform the duty, the disposition of the engine power being one locomotive at the head, one in the centre, and the third at the rear of the train. The general practice is to rush the bank, but owing to a crossing station being placed at Dell, one mile below the summit, the train is in danger of being pulled up at a critical moment.

Through Dell station extends a level section 288 yards in length. The train, belching for all it is worth, because it is

pulling against the collar, comes over the brow at a snail's pace, but directly the level stretch is entered, and owing to the steam pressure being maintained, the engines quickly gather tremendous speed. In this manner they get a magnificent swing on the train to buck against the last lap of the 1 in 30 grade which leads to the summit. The engine effort expended is tremendous, the roar and ejection of dense clouds of smoke and exhaust steam presenting an impressive spectacle.

Continuing westwards, the line undulates somewhat more gently to Ladysmith, 191 miles out of Durban, and at an altitude of 3,284 feet. At this point the railway bifurcates, the one arm continuing northwards to the Transvaal border, while the other swings due west to enter the Orange River Colony, proceeding by way of Beth-



The bridge supported by the South African Railways.

THE MASSIVE STEEL BRIDGE SPANNING THE ORANGE RIVER AT BETHULIE.

lehem and Marseilles to Bloemfontein, where it connects with the main line of the Cape system extending to Pretoria. From Bethlehem, to reach which the Drakensberg range has to be crossed at an

at first, towards the Transvaal boundary. The Biggarsberg range is first crossed, the summit level 233 miles from the coast being 4,300 feet. After switchbacking through Newcastle and Utrecht, the foot



Photograph supplied by the South African Railways.

WATERVAL BOVEN TUNNEL ON THE DEVIATION LINE, TRANSVAAL.

This re-alignment displaced the old rack section, $4\frac{1}{4}$ miles in length.

altitude of 5,520 feet, a connecting line runs north-westwards to Kroonstad, where a junction is effected also with the Cape line coming up from Bloemfontein, thereby giving Durban an additional railway connection with the Rand and Pretoria. A third link is also under way, construction having been commenced upon a cut-off running northwards from Bethlehem to Balfour, where connection is to be effected with the Transvaal section of the old Durban-Johannesburg main line.

Leaving Ladysmith, the main line enters upon an almost continuous climb, steady

of the Drakensberg range is met at Ingogo on the 4,000-foot altitude line. A smart upward pull for some 22 miles through Laing's Nek and Majuba brings the line to the Transvaal boundary at Charlestown, where the train notches a level of 5,400 feet.

The 304 miles of main line between Durban and Charlestown represents probably one of the stiffest pieces of railway construction in Africa, inasmuch as barely 30 miles of the whole length is level. In making the journey from the coast the trains have to overcome a total vertical



Photo, 1904, supplied by South African Railways

THREADING THE SOUTH AFRICAN MOUNTAINS.

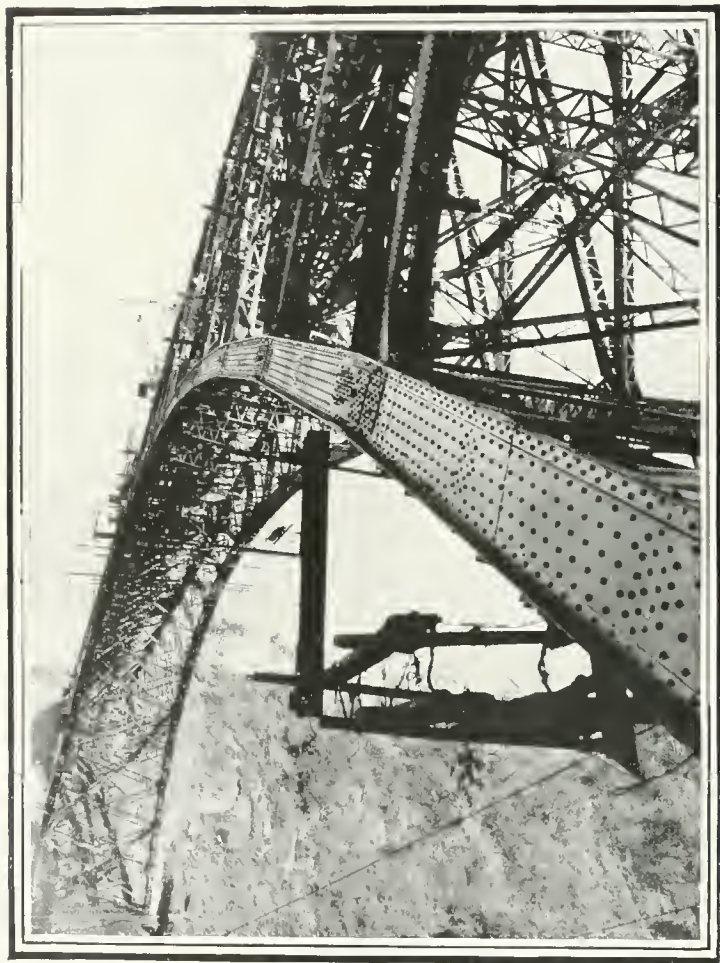
This photograph, showing the track on the Hottentot—Holland route, conveys a vivid impression of the broken character of the country.

elevation of 12,000 feet in this distance. Under these circumstances the problem of economical operation is somewhat searching. But the grades and curves are inimical to such aspirations. The line has been improved considerably, but the physical conditions are so adverse that little relief can

alignment free from such sharp curvature and heavy banks, no decisive step has been taken.

But possibly the most remarkable line in the southern extremity of the continent is that whereby the old regime in the Transvaal obtained an outlet to the coast without traversing British territory. This is the railway running through Portuguese East Africa from Lorenzo Marques (Delagoa Bay) to the frontier at Koomati Poort, and thence westwards to Pretoria and the Rand. As the crow flies tide-water is about 270 miles from the Rand, so that it constitutes the natural outlet from the gold centre, at all events for freight traffic, owing to the shorter haul.

When this railway was constructed, a quarter of a century ago, by the Boer Government, heavy traffic was not anticipated, so it was built somewhat flimsily to the 3 feet 6 inches gauge, and laid with light metals. Money was somewhat tight, so the engineers laid the road in the cheapest manner, reducing earthworks to the minimum by running round every obstruction, no matter how insignificant it might



THE ARCH OF THE VICTORIA FALLS BRIDGE FROM BENEATH DURING CONSTRUCTION.

be obtained. The situation has been met to a certain degree by the introduction of very powerful locomotives and rolling stock of the minimum dead weight and maximum carrying capacity. Time after time the question of abandoning the present road for main line traffic has been debated keenly, but although new surveys have been run between the coast and the Transvaal frontier in order to obtain an improved

be. Consequently the route is somewhat circuitous as compared with an alignment which would be run to-day, Johannesburg being 350 miles by rail from Delagoa Bay. Despite this fact, however, it has an advantage of about 135 miles over the Natal link with the Rand.

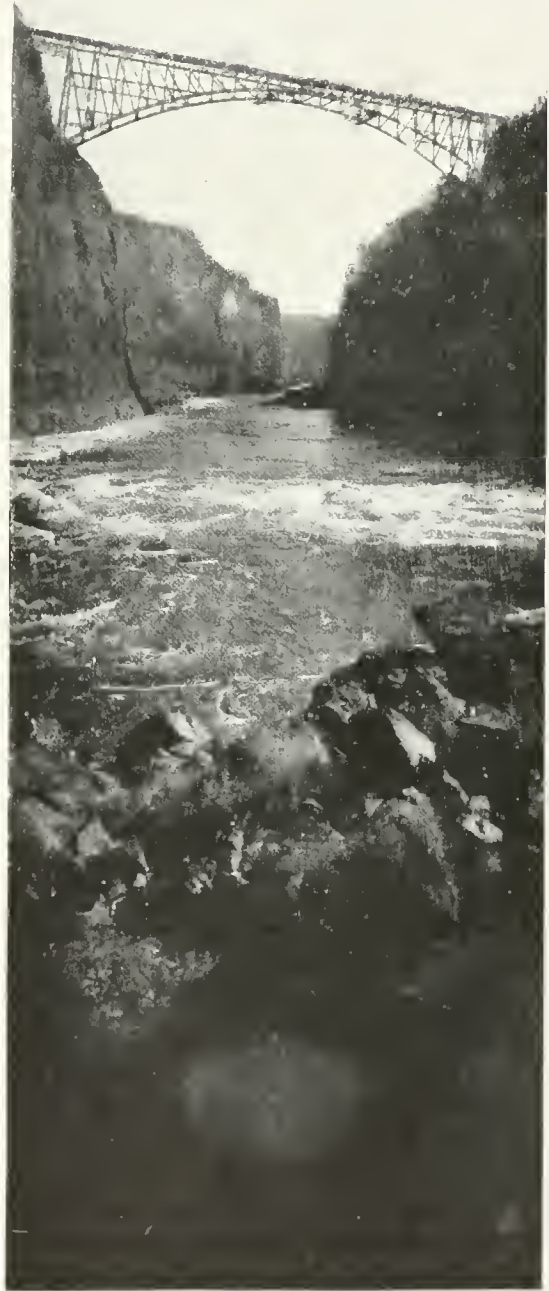
Here again the configuration of the country was dead against the builders. Leaving the coast, an uphill pull of extreme

severity was encountered. In the first 100 miles a difference of 1,340 feet in altitude has to be overcome, while in the second 100 miles the metals are lifted to an altitude of 6,460 feet at Belfast. At one point between Waterval Onder and Waterval Boven no less than 600 feet had to be negotiated in a distance of $4\frac{1}{4}$ miles, and the difficulty was overcome by laying a rack, with a maximum gradient of 1 in 27, through this section.

When the Transvaal railways came under British sway this rack section became the limit of the railway. Heavier and more powerful rack locomotives were put into service, but the relief accruing from such a move was very insignificant. Finally the possibility of eliminating the rack section was discussed, and Mr. B. P. Wall took the matter in hand. He ran surveys through the admittedly difficult $4\frac{1}{4}$ miles of country separating the two villages, but at length found a location which would permit adhesion working and with no grade heavier than 1 in 50.

The improvement met with approval, and was undertaken without further delay. The task was somewhat intricate owing to the lack of elbow-room. Heavy side-hill excavation, tunnelling, revetment, and the introduction of numerous curves were inevitable. When the scheme was first proposed it included a viaduct to overcome a point where the waterway set against the slope of the hill, and £10,000 were set down for the cost of this item alone. But while the work was under way the engineer suddenly conceived the idea of diverting the river, thereby eliminating the viaduct. The probable cost of the diversion was compared with that of the first proposal, and, being favourable, was preferred. As a matter of fact it proved the cheaper solution, the diversion costing less than £9,000.

By cutting out the rack section of $4\frac{1}{4}$ miles and building an adhesion line between Waterval Onder and Waterval Boven the



THE HIGHEST BRIDGE IN AFRICA.

The famous Victoria Falls arch, having a span of 500 feet, which carries the Cape to Cairo Railway across the Zambesi River Gorge, 420 feet above the boiling rapids.

distance between the two points was just doubled—8½ miles. On the other hand the grade was pulled down from 1 in 27 to 1 in 50, and the capacity of this section was raised to the rest of the system. The total cost of straightening this kink in the main freightway between Johannesburg and the coast was about £140,000, and it ranks as one of the most interesting and difficult examples of railway engineering in South Africa.

For some years the most northern point attained by the western main line of the Cape system was Fourteen Streams, whence the De Beers line ran north-eastwards to the Rand. When Cecil Rhodes conceived his great dream of a railway backbone to the continent, having one end resting on the Mediterranean at Cairo and the other extremity upon the Atlantic Ocean at Cape Town, his obvious unpinning-off place was Fourteen Streams. But he maintained that the Cape Government ought to drive their northern outpost farther into the interior. The Government scarcely saw eye to eye with him, since it meant traversing unpopulated and undeveloped country. However, the Empire-builder became so insistent that at last they decided to run it a further 127 miles northwards to Vryburg.

Rhodes accepted this decision, and struck his road of 3 feet 6 inches gauge northwards from Vryburg through the heart of what is now Rhodesia to the southern shores of Lake Tanganyika. Work was commenced in 1893, and eighteen months later it had penetrated 96 miles to Mafeking. From this point the metals were driven across the eastern edge of the Kalahari desert to Buluwayo, the 522 miles being completed in something like 3¼ years. Indeed, work was pushed forward so vigorously that the last lap of 129 miles from Palapye Road to the capital of Rhodesia was completed in five months!

From Buluwayo a north-westerly route

was followed to tap the Wankie coalfields. Crossing the Zambesi River, the engineers swung towards the north-east to Broken Hill. Here construction was brought to a standstill for a time to permit the determination of the route beyond. The Germans balked the idea of carrying the metals through their territory fringing the eastern shores of Lake Tanganyika, which would have enabled the Uganda Railway to have been tapped, but the Belgians proved more amenable. Accordingly the line has been taken round the western side of the lake, traversing the copper country of Katanga, linking up with the Congo Railways, and has now reached a point near Kambove. To-day one can enter a train at Cape Town and be whirled for 2,000 miles through the length of Africa without changing carriages. Simultaneously with this northward advance the Soudan Railway has been steadily creeping southwards, so that Rhodes' "phantom" is within measurable distance of consummation.

In driving the Cape to Cairo Railway northwards two great obstacles were encountered. The first was the fissure through which the Zambesi thunders and boils after tumbling over the precipice known as the Victoria Falls. The depth of the chasm and the precipitous nature of the cliffs demanded a bridge of daring design, and only one arch span was possible.

The Victoria Falls Bridge.

At the point where it was decided to span the rift the opposite cliffs were 500 feet apart, while the water was some 400 feet below. It was decided to provide a double-track bridge. Construction was carried out upon the cantilever principle from both banks simultaneously. In order to enable material to be supplied to the north bank, a cableway was stretched across the gulch. These facilities were utilised not only for the immediate requirements of the bridge, but also for transporting supplies for continuing the railway beyond while the gap was being spanned.

The bridge is of graceful design. At the point where the steelwork springs from the cliff face on either side the structure measures 105 feet in depth between the top and bottom members, tapering to a depth of 15 feet at the crown of the arch. At deck level the extreme width of the bridge is 30 feet, spreading out to 54 feet at the

building up to this time had not been a duty assigned to him. Toiling 400 feet in mid-air above a frothing, boisterous waterway no doubt is exciting adventure to a native, but the liability of accident could not be overlooked, and mishaps are expensive even when dependence is placed upon black labour. Accordingly, when the



THE OPENING OF THE VICTORIA FALLS BRIDGE.

skewbacks. Although erection was carried out almost exclusively by native labour, and notwithstanding the difficult character of the task, the bridge was completed in the remarkably short time of eighteen months. The Victoria Falls Bridge at the time of its completion ranked as the highest in the world, and although this distinction has since been assumed by another big undertaking, it still ranks as the loftiest work of its class in Africa, the rail level being 420 feet above low water.

A somewhat novel innovation was made in connection with the erection of this bridge. The Kafir may be a clear-headed and steady workman, but lofty bridge-

two sides of the arch commenced to grow from the opposite cliffs a large net was slung across the gorge beneath the structure to catch "falling tools and nigger boys." By the adoption of this precaution the setting of the steel of the Victoria Falls Bridge was rendered completely safe to life and limb. This simple and efficient expedient, which apparently had not aroused a moment's thought heretofore, is extensively adopted now. In the early days of railway building a life more or less, even among white men, was considered an insignificant detail, and accordingly great risks were permitted and run. But nowadays the consular representative and the native agent are uncannily active and inquisitive.

The loss of a toiler to-day, even though it may be only a nigger, is not permitted to escape unnoticed, and the vigilant authority does not hesitate to make the contractor pay for any contributory negligence. Accordingly, in the majority of big bridge building achievements, especially where native labour is utilised, the protective net below the lofty maze of steel has become a conspicuous feature.

North of the Victoria Falls the builders were confronted with the Kafue River, the most important tributary to the Zambesi. In this instance it was not the level of the river in relation to the grade which worried the engineers, but its great width—1,300 feet. The Kafue River is somewhat shallow during the dry season, the average depth being 9 feet, but in times of flood it rises to 36 feet.

A lengthy bridge was required, and finally it was decided to divide it into thirteen 100-foot spans. It is of the lattice girder through type, and was erected by the pontoon method. The steelwork was prepared in England, shipped to Cape Town, and hauled 2,000 miles up-country to an improvised yard upon the river banks. A steel pontoon was likewise shipped out to Central Africa in sections, reassembled, and launched. While the steel was being prepared the concrete piers were hurried

forward. The actual work of construction was supervised by Mr. A. L. Lawley, and he gauged operations so neatly that the piers were completed by the time the whole of the spans, each of which weighed 56 tons, had been riveted up and were ready for setting in position. The engineer allotted sixteen days for this part of the work, and if everything proceeded smoothly, as anticipated, the bridge would be completed before the season broke. But, as a matter of fact, the work went forward with such a swing that the whole of the thirteen spans, representing a dead weight of 728 tons, were transferred to the pontoon and set upon their respective piers within eight days! By the time the two banks had been connected by the bond of steel £50,000 had been expended.

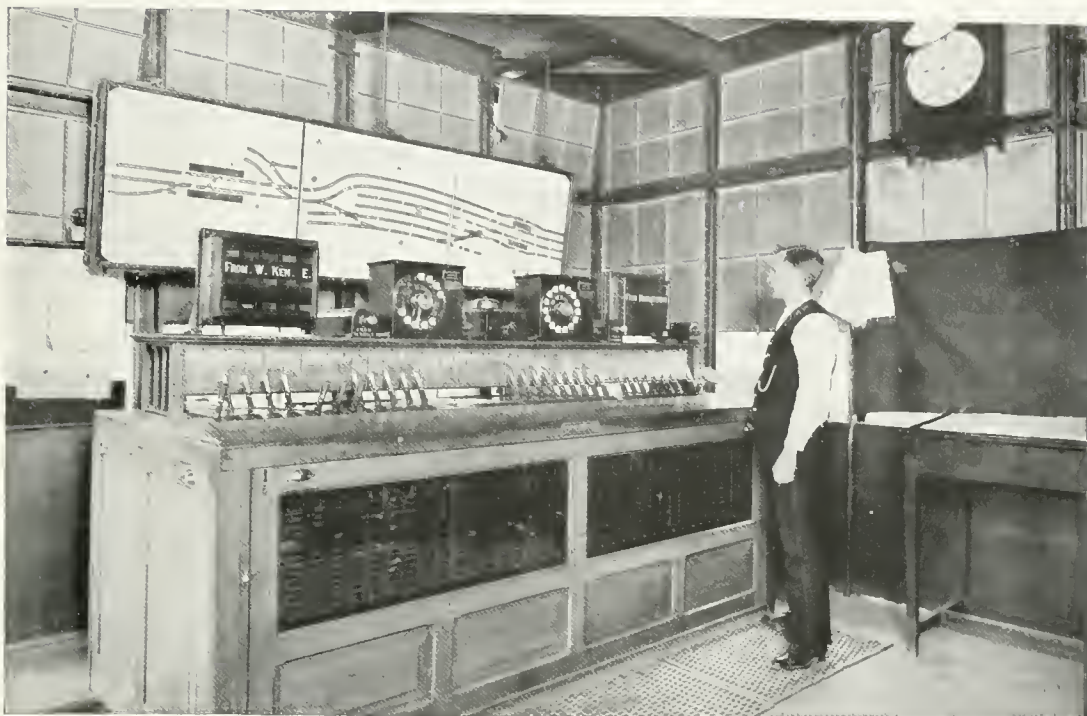
Upon the conclusion of the Boer War a scheme for unifying the various railways of British South Africa was formulated and became law. To-day practically all the railways of the various colonies are worked by the State. The total network in operation comprises some 7,500 miles. An active extension policy has also been fostered—over 1,000 miles of new roads being under construction and plotted—upon the completion of which nearly 9,000 miles of line will be under Government control.



THE LONGEST BRIDGE IN AFRICA. ACROSS THE KAFUE RIVER.

It is 1,300 feet in length, divided into thirteen spans.

By courtesy of A. L. Lawley, Esq.



Photograph by E. Mühner, Wandsworth.

ONE OF THE SIGNAL BOXES AT WEST KENSINGTON JUNCTION ON THE METROPOLITAN DISTRICT RAILWAY, SHOWING LEVER FRAME AND ILLUMINATED TRACK DIAGRAM.

Running Fifty Trains an Hour

THE WONDERFUL AUTOMATIC SIGNALLING SYSTEM OF THE METROPOLITAN DISTRICT RAILWAY



ONE of the most remarkable features of contemporary railway developments has been the rejuvenation of the Underground Railways of London. Steam working and all associated therewith were scrapped, lock, stock, and barrel, to make way for modern motor-driven rolling stock of the latest type. The adoption of electricity, in addition to bestowing other innumerable advantages, enabled considerable accelerations to be effected, together with the introduction of more frequent services.

The rehabilitation of the District was complete and startling. The saving of

minutes and the doubling of the number of trains per hour impressed the city toilers to an unexpected degree. So much so that within a very short while after the inauguration of the new electric era the service became totally inadequate. Further trains were added, and the running of the line was speeded up until at the present time some fifty trains per hour can be operated, which represents a capacity unapproached by any other road of this character in the world. Moreover, by clever timing arrangements it became possible to initiate "non-stops," which under steam conditions were quite impossible.

The maintenance of 90 and 75 seconds'

services upon such a line as the District, and also the Tubes, indicates that the signalling arrangements must be of a remarkable and strikingly perfect character. So they are. In fact, the control and protection of the trains constitutes the most wonderful feature of the operation of the system. In a previous chapter the elaborate and ingenious signalling methods in vogue at the New York terminus of the New York Central and Hudson River Railroad have been described, but this installation is not comparable with that used in London to-day, although as a

ated by compressed air controlled by electro-magnetic valves. The employment of signalmen is restricted to junctions, cross-overs, and so forth. On the straight through roads the trains are governed and protected entirely by automatic methods.

The automatic signalling lay-out of a typical straight through road is explained in Fig. 1. One running rail on each road is divided into "sections" of determined length, by means of insulated fish-plates B. The length of the section, according to circumstances, varies from 450 feet to 2,000 feet. Each of these sections is

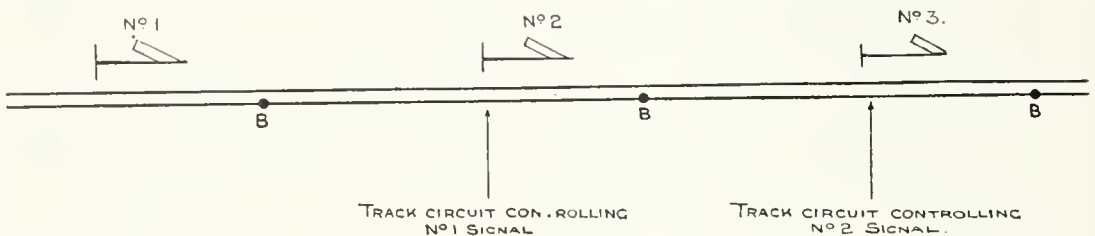


FIG. 1.—LAY-OUT OF AUTOMATIC SIGNALLING UPON A TYPICAL LENGTH OF THROUGH ROAD.

matter of fact it was modelled after the English system.

When the modernisation of the Underground Railway was taken in hand, it was decided to reduce dependence upon the human element in connection with signalling to the absolute minimum. Inventive and mechanical ingenuity had triumphed to such a degree as to favour such a movement. The Mackenzie, Holland and Westinghouse interests had perfected an electro-pneumatic system which fulfilled the required conditions concerning reliability, durability, efficiency, and, so far as is possible with automatic mechanical devices, infallibility also.

While an exhaustive description of the working of this system would demand technical details which would baffle all but the engineer, it is possible to extend a few lucid facts concerning the broad principles of the idea, to demonstrate its bearing upon the solution of the somewhat complex rapid intra-mural transportation problem. The points and signals are oper-

called a "track circuit" and controls the signal to the rear. This control is accomplished by means of a relay, which is carried in a cast-iron box placed beside the line near the insulated fish-plate. The signal itself is of the conventional semaphore type counterbalanced so that normally it assumes a horizontal position, indicating "danger."

When the road is all clear, the signal is held in the "off" position—that is, lowered, because the electro-magnetic valve admits compressed air into the cylinder of the signal motor, actuating the semaphore arm. Immediately a train enters the clear section the electro-magnetic valve is de-energised, and permits the air to escape, with the result that the semaphore arm returns by gravity to danger, and remains in that position until the last pair of wheels of the train has passed out of the section in question, when the signal once more drops. But before this takes place, as reference to Fig. 1 will show, the next signal ahead is put to danger, so that there is

always at least one signal at danger behind a train. In other words, there is always a section or a block between two succeeding trains.

The signal cabins, which are necessary to control junctions, cross-overs, and so

of the District signalling system. As a matter of fact this railway was the first in the world to adopt it in connection with signalling. So completely successful has it proved that when the Grand Central terminus in New York was reconstructed, the American railway copied the London idea, as being the most suited to its peculiar conditions. It must also be pointed out that all the signals worked from these cabins are controlled automatically by the track circuits.

But, no matter how excellent and perfect in its operation a signalling system may be, it is of little value if the signals given are permitted to go unnoticed by the motor-man in charge of the train. In order to guard against any dereliction of duty, or to prevent an accident in case of the driver being suddenly incapacitated or seized with illness, further protective devices are incorporated. There is the automatic stop whereby the train is pulled up. This stop comprises a "T" headed arm operated by a compressed air motor, which works in conjunction with the signal. When the latter is in the "off" or danger position, the arm A, shown in the illustration on this page, is in the upright position. Each

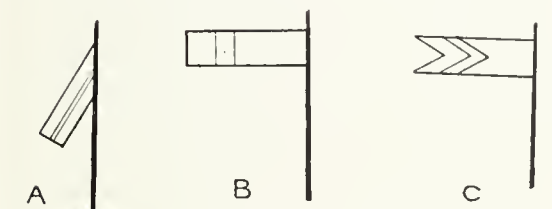


FIG. 2.—THE THREE TYPES OF SEMAPHORE ARMS.
A. Automatic. B. Cabin Controlled. C. Repeater.

forth, are fitted with lever frames whereby the compressed air for working points and signals is controlled. Above the frame is fixed an illuminated diagram, on the glass front of which is inscribed all the roads governed by that particular cabin. Within the diagram are placed small incandescent electric lamps, and the diagram is so arranged that each track-circuited section is illuminated separately. Normally all the sections are lighted upon the diagram, but directly a train enters a block the lamps in that particular section on the diagram are extinguished, so that the train's presence is indicated by a dark patch. As the train leaves the one and enters the following block, the former becomes re-illuminated, while the latter in turn goes out. In this manner the signal-man is able to follow the passage of a train, and is always apprised of the exact position thereof within the area governed by his box. This illuminated track diagram constitutes one of the most noticeable features

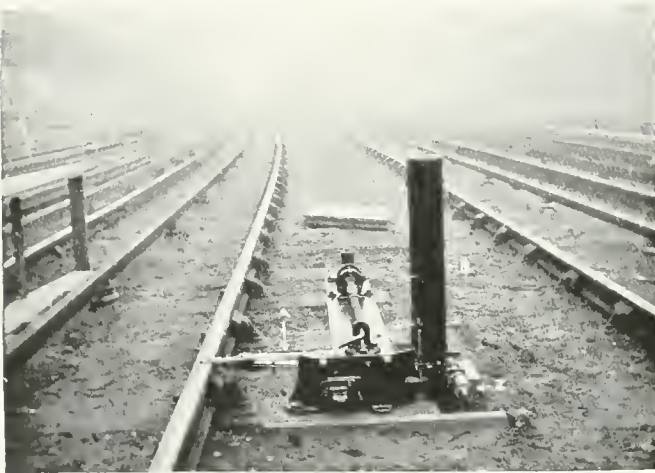


THE AUTOMATIC STOP WHEREBY TRAINS ARE BROUGHT TO A STANDSTILL INDEPENDENTLY OF THE MOTOR IF THE SIGNALS ARE AT DANGER.

train is fitted with a trip cock which is actuated by the train stop should a train pass a signal set at "danger." This operation of the trip cock causes the brakes to be applied suddenly, and is so effective that, even if a train be travelling at full speed, it can be brought to a standstill within about 250 feet, which is considerably less than the spacing distance maintained by the signals between succeeding trains.

On the District Railway the semaphore signal arms are of three distinctive types,

employed to guide and protect trains under such adverse conditions. This apparatus, shown in the accompanying illustration, consists of a vertical box, B, containing a magazine which may be loaded with 50 detonators. When the signal is at danger, the horizontal arm A swings round to place a detonator on the track rail. Each machine is fitted with a whistle, Z, which is set in such a manner that directly the magazine supply has been reduced to, say, six detonators, it gives a loud warning blast, intimating that it requires recharging, the sound continuing until this operation has been completed. The automatic fogging machine is operated by compressed air motors, works in conjunction with the signals, and is supplementary to the latter under conditions of thick weather.



THE AUTOMATIC FOGGING APPARATUS FOR PLACING DETONATORS ON THE RUNNING RAIL.

the reason for which is explained in Fig. 2. That marked A is a red arm with a thin white line running lengthways down the centre, and indicates that it is automatically operated; B is a red arm with a white bar near the end, and indicates that it is controlled from a signal cabin; while C is a yellow arm with a black "V" stripe and a notched end. This is a repeater signal, and is used to show the position of the next signal ahead.

As is well known, fog, to which London is particularly subject during the winter months, is able to paralyse even the most perfectly operated system far more completely than any other visitation of Nature, but in the case of the District Railway its interference is reduced to the lowest limits possible. Automatic fogging signals are

All automatic mechanical devices suffer from one defect, if such it can be called. This is the liability to fail from a breakdown of the apparatus, due to some inherent fault in the material of which it is made,

and which human investigation cannot detect. Consequently, it is imperative that, in the event of such a fault occurring, the signal should not give a false warning, and thus misguide the motorman. In the signalling system installed upon the District Railway no apprehensions need be entertained. In the event of a breakdown or defect developing the signals affected return to danger, notwithstanding that possibly the track may be all clear. The possibilities of a false signal being given is so remote as to be beyond contemplation. It is estimated that the liability of failure is about 1 in 3,000,000 movements of the signal, which serves to convey some idea of the perfection of the system, the preparation and strength of the component parts, and the remarkable ingenuity of its design.

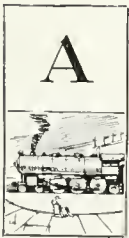


SOLDADO STATION, IN THE HEART OF THE GREAT SALT LAKE DESERT.

The white surface beside the railway is not snow, but a huge pan of salt 15 miles long by 8 miles wide, and as solid as rock.

“The Feather River Canyon Route”—II

SEVENTY-FIVE MILES OF RAILWAY WHICH COST £1,500,000



AT a distance of 75 miles from Salt Lake City the line reaches the eastern edge of that dreary flat known as the Great Salt Lake Desert. It is a dismal waste, where, until the arrival of the railway, not a sign of life was to be seen. Mankind, animals and birds shunned it in common. Here and there it is as white as a snow-driven plain, and under the brilliant glare of the summer sun is blinding. The railway makes a bee-line across it for 46 miles, to Wendover, as if the engineers and builders hurried to leave the white blister behind as soon as possible.

In the summer this desert is unbearable. The salt sirocco is a thousand times worse than the dust storm of the Sahara; the

air becomes saturated with minute particles of salt and dust, which, penetrating the eyes, nostrils, mouth and nose, set up torture inconceivable. In the wet season the salt and dust become converted into a viscous slime, more tenacious than the finest liquid glue yet contrived, which defies removal by anything less than a knife.

When the builders reached its uninviting edge they paused. They decided to get across the ugly stretch speedily and effectively. Elaborate borings were carried out at frequent intervals along the line of the location survey pegs to discover the character of the soft top soil. These showed that a solid and firm foundation existed at a depth ranging up to 14 feet. At one place the line bisects a huge salt pan, the



A HEAVY WESTERN PACIFIC FREIGHT TRAIN THREADING

Despite the difficult mountainous country traversed, the ruling gradient throughout the 921 miles between Salt Lake but at flood it is a raging torrent, the



THE TORTUOUS FEATHER RIVER CANYON.

City and San Francisco does not exceed 52.8 feet per mile. In the dry season the Feather River is a mere brook, difference in season levels being 45 feet.

glistening white crystals of which stretch for 15 miles north and south by 8 miles from east to west. The salt, having packed and compressed, is as solid as a rock, so that no fear of an unstable foundation was entertained here.

Toiling under such conditions was no task for the tenderfoot. The builders made elaborate preparations for bringing up ample supplies of water, because the dust, rising into the air in clouds, provoked heavy and continuous calls for the mug and bucket to assuage a thirst such as salt only can precipitate. Many a man suddenly threw down his tools to crawl into the welcome darkness of the caboose to rest his eyes, which had become bloodshot from the glare and choked with the dust, setting up excruciating agony.

The builders had recourse to a novel method of construction which expedited progress very materially. The men could not stand on the surface of the soil, as the feet sank into the drab flour. So longitudinal planks were laid down, on which the men stood to lay the sleepers and metals upon the face of the desert. Then a trainload of ballast backed out on to this track and shot its contents. After the empty trucks had been pulled away, the track, with the sleepers attached, was lifted, and the material spread underneath, this process being continued until the desired level of the grade was gained. The embankments are very broad and low, and, as was anticipated from this method of construction, settlement has been a negligible quantity. When the stretch of solid salt was gained there was no necessity for any ballasting whatever. The surface was just levelled off, so that the solid salt acts as the permanent way.

Surveying the white waste from the railway train until it melts into a haze upon the horizon, one is apt to think that the company here are confronted with 40 miles of absolute sterility, incapable of

yielding a pennyworth of traffic. As usual, first impressions are wrong. On the belt the mineral is of high commercial value, as it assays up to as much as 97 per cent. of salt. It has not been exploited hitherto, owing to the complete lack of transportation facilities, but now that the railway has come the vast deposits are being developed. Not many years will pass before the dismal white plain is dotted with shacks and buildings engaged in the extraction of the white mineral.

In Nevada the engineers were forced across another inhospitable stretch of country, dotted only by clumps of sage-brush, but at places defying even this stunted vegetation sufficient nourishment to flourish. There is nothing but a terrifying sea of fine alkali sand, which drifts hither and thither in clouds, like smoke. The lack of water in these arid regions hit the railway company somewhat hard at first. The desert itself for the most part fails to yield a drop, even when artesian wells are driven down to extreme depths. When a spring was tapped, invariably the water was found to be so brackish as to be useless, because it would have played sad havoc with the internal organs of a locomotive. The engineers overcame this drawback by bringing welcome pure streams from afar through pipe lines. On the eastern side of the desert a mountain spring was tapped 800 feet above the railway track, and the difference in level is sufficient to carry the water through a 6-inch pipe to a point 16 miles away. In another instance the water has to rush for a distance of $21\frac{1}{2}$ miles through a similar conduit to the stations' tanks, so that the engines may take on sufficient supplies to slake the heavy thirst provoked by the rush over the desert.

Here and there, even among the uneventful and comparatively gently undulating country east of the mountains, some striking evidences of the engineers' in-

Across
the Alkali
Desert.

genuity to preserve the 1 per cent. grade are manifest. The Humboldt River country received special attention owing to the ill-fame of this waterway, which at intervals displays a desire to wander with apparent aimlessness over the countryside to cut a new channel. By building massive embankments at treacherous spots, and carrying all bridges out in steel upon heavy concrete piers, all dangers in the Humboldt country are overcome. In getting through the Silver Zone Pass to approach the Sierras a sudden difference in level had to be negotiated. As the crow flies the distance is about one mile, but had the engineer taken that course a bank rising $157\frac{1}{2}$ feet per mile would have been unavoidable. This was ruled out of court, so the engineer described a huge horseshoe curve with his ribbon of steel to gain the pass, and although the loop is 10 miles in length, yet the grade does not exceed 52.8 feet per mile.

But it was in the mountains and through the Feather River Canyon that the builders

**The
Beckwourth
Tunnel.**

experienced their greatest difficulties. On the plains they had suffered from absence of water; here the excess was

their anxiety. The Divide is crossed at Beckwourth, at an altitude of 4,956 feet, by a tunnel through the peak 6,006 feet in length, the fall from end to end being in a westerly direction. This bore, in common with the other big tunnels, is 17 feet wide by $22\frac{1}{2}$ feet in height above the sub-grade. The arch is semi-circular, and where lining is necessary it is of segmental section carried out in timber.

It was not a question of merely blasting a pathway at the desired level out of the solid rock through the Feather River Canyon. At many places the shelf could not be cut, owing to a big cleft in the rock. This gap had to be filled. The engineers built a heavy retaining wall from the bottom of the rift to the desired level, filling it in with boulders set in cement, and keying the

whole firmly to the rock behind. Such artificial ledges are as solid and stable as the mountain side itself. One of the heaviest pieces of work of this nature is 40 feet in height.

At another point, $21\frac{1}{2}$ miles west of the Beckwourth Pass, the river channel had to be turned to one side to provide room for the railway.

**Diverting
the River.**

A heavy piece of crib-work was erected for the purpose. This comprises layers of logs laid at right angles, and notched near the ends to form saddle joints. The hollow timber stack or wall is filled with boulders and loose earth, which, packing tightly, forms a solid embankment. In another instance the bed of a creek threatened the safety of the line. Curvature prevented the engineer cutting a track in the solid rocky wall, so he set out to divert the torrent. A heavy masonry wall was built, and a new channel paved to lead off the water. The stream thus was deflected so as to run under the railway at right angles.

In order to ease the pressure of the water when the river is in flood its course was widened at places by blasting away obstructing boulders in the stream and shoulders of the mountains which dropped into the channel. The increased width thus provided enables the water to rush forward without setting up violent whirlpools in the vicinity of the railway. Here and there the sharp twists which the river makes on its turbulent race to the sea threatened to imperil the safety of the permanent way by scouring away the toe of the mountain flank whereon the metals are laid. In order to protect the grade in such instances a heavy timber crib or wing dam is thrown out into the river. Consequently the water swinging round the bend cannot strike the bank fairly and squarely, but is obstructed and forced round the head of the jetty-like timber structure projecting into the channel.

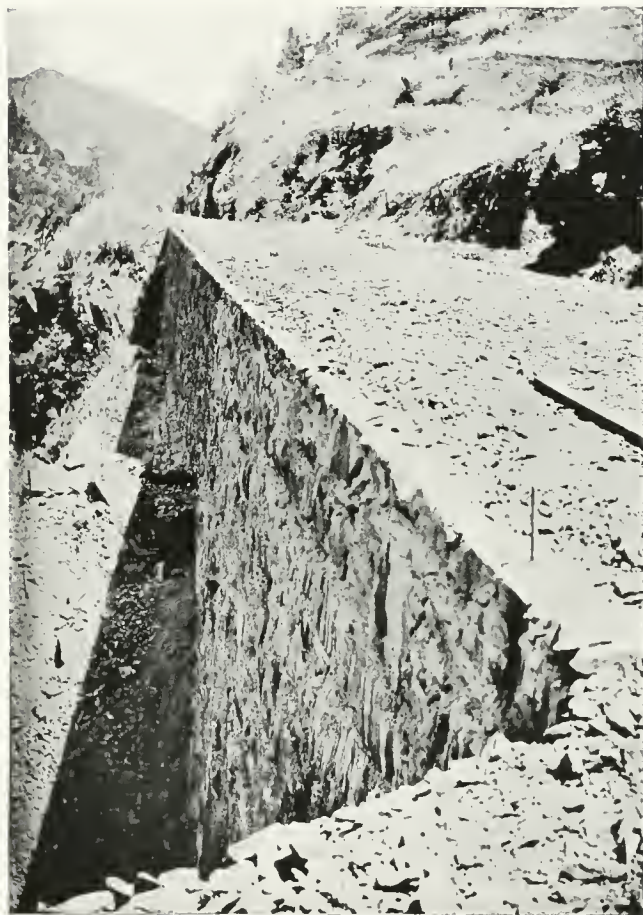
While a gallery was hewn and cut out

of the solid rock so far as practicable, it was impossible to cleave a way through huge humps which drop sheer into the water from a towering height. Such obstacles have been tunnelled, and there

Two of the heaviest works on the whole 921 miles of the railway between Salt Lake City and San Francisco are in this canyon, one being the "Reverse Curve" Bridge at Big Bar, which comprises through

truss skew spans, two of 112 feet, and the central span of 224 feet, carried on substantial concrete piers and abutments. The other is 14 miles farther east, and this consists of a 260-foot through truss span and a plate girder span of 50 feet. Two other notable bridge structures are the Spanish Creek Viaduct, the highest tower of which is 148 feet, and the Willow Creek Viaduct, which spans 1,005 feet at an elevation of 168 feet above the creek. This viaduct contains 1,200 tons of steel. It was on the Spanish Creek Viaduct that the Golden Spike was driven, the last rail being laid and bolted up near the centre. Considering the length of the railway and the heavy work involved in threading the mountains, the extent of steel bridging is somewhat small, as the aggregate is only 41, representing 9,161 lineal feet, for which 7,780 tons of steel were required.

It was the earthworks which ran into money on this railway, as Mr. Bogue, the engineer in chief, explained to me. Probably the section through the Feather River



MASONRY WALL THROWN ACROSS A RIFT IN THE MOUNTAIN, AND FILLED BEHIND TO PROVIDE A SHELF TO SUPPORT THE METALS.

are some 33 of these short burrows through the 116 miles of the canyon, the length of which averages from 175 feet to 1,000 feet. Many, being driven through solid rock, are not lined, except at the portals. The short tunnels are excavated out to a width of 16 feet, although the height is the same as in the larger works of a similar character.

Although the line is forced from one side of the canyon to the other from time to time, there is no particularly heavy bridging, owing to the gulch being somewhat narrow.

Canyon ranks among the most expensive ever completed in the United States. It was all side-hill excavation and tunnelling for a matter of 75 miles, and practically through solid rock the whole way. In such circumstances an average of £20,000 per mile for the road alone, exclusive of bridging and metals, although it may seem prohibitive, was reasonable. Had the limitations concerning the gradient not been so inflexible the canyon might have been traversed for a much less sum. But nowa-

days it is the grade which counts. Still, £1,500,000 for 75 miles conveys some idea of what it costs to build a railway in conformity with modern ideas through the western American mountains.

One of the greatest difficulties encountered in this section of the work was in connection with the transport of materials and provisions. The river was useless as a highway, and there were no trails. The contractors had to build a *tête-road* through the canyon, above the location, so as to be in touch with camps and scattered forces engaged in construction. This road had to be built before a shovelful of earth was moved on the grade to enable ample supplies to be cached at frequent intervals. Over £100,000 was spent by the contractors to complete this preliminary work through the canyon—a highway which became useless after the line was finished.

The labour for construction was recruited from all parts of the world, but Hindoo workers were predominant upon the mountain section. Large numbers of Scandinavians and Italians were employed for blasting, in which they are adept, while other nationalities, the hoboes and Hindoos were engaged in handling the spoil brought down by the explosives. The contractors displayed remarkable skill in keeping the camps and men well supplied and free from any outbreak of disease, which in itself is no easy matter when such heterogeneous masses are gathered together in isolated communities in the wilderness.

There was one exciting incident during construction. The town of Oroville was flooded out during the spring of 1907. The plight of the inhabitants was pitiable, as they were cut off completely from the outside world for ten days. The railway builders relieved the situation by placing the supplies for the camps at the disposal of

the citizens. It saved Oroville from a dire calamity, but the contractors had to redouble their efforts after railway communication was restored to secure the safety of its own army in the far-flung-out line of camps in the canyon beyond.



ROUGH GOING THROUGH THE FEATHER RIVER CANYON

Showing entrance to a short tunnel through a spur 30 miles east of Oroville, California.

The character of the undertaking did not lend itself to the practice of unorthodox ways and means of completing the work. The tools for the most part comprised steam shovels for handling both loose and broken rock. In fact, it was found that well-tried methods were the most suitable. One firm, who had taken over a sub-contract for a stretch of line in the canyon, thought it would get through its section quicker by

sluicing down the mountain sides with hydraulic monitors. It had scarcely got started when trouble arose. The Feather River empties into San Francisco Bay, and visions of silt brought down by the monitors and finding its way into the river, to be disgorged finally into the bay, were conjured up by the authorities. It was futile to explain that the spoil could not get into the waterway. The work must be stopped; the law was being infringed. The threat of dire penalties peremptorily extinguished this manifestation of ingenuity; reversion had to be made to safer methods from the official point of view.

The tunnel-borers experienced hard work and exciting times in driving one or two of their burrows. The Spring

The Spring Garden Tunnel.

Garden Tunnel, the longest on the line, sprang the greatest number of surprises in the course of its 7,306 feet. The rock-hogs started carving through solid rock, which external examination suggested was continuous. But they had not gone far when the rock gave way to a thick vein of mud and water. Heavy lining became necessary to hold back the soft material, which caved in rapidly. The men ploughed their way slowly through 700 feet of this treacherous soil, only to blunder into a strata of black basalt, which was pulverised in a remarkable manner. By dint of great effort they struggled through this obstacle, and then their discomfiture was completed. The drillers struck an old river bed; down came sand, boulders, and silt in what appeared to be a never-ending stream, which, however, was mastered finally. In lining this tunnel heavy timbering and concrete were resorted to practically from end to end.

The completion of the Western Pacific Railway not only secures an independent outlet to the Pacific for the Denver and Rio Grande Railway, but it will be a valuable feeder to the latter system. It traverses country rich in agricultural, mineral,

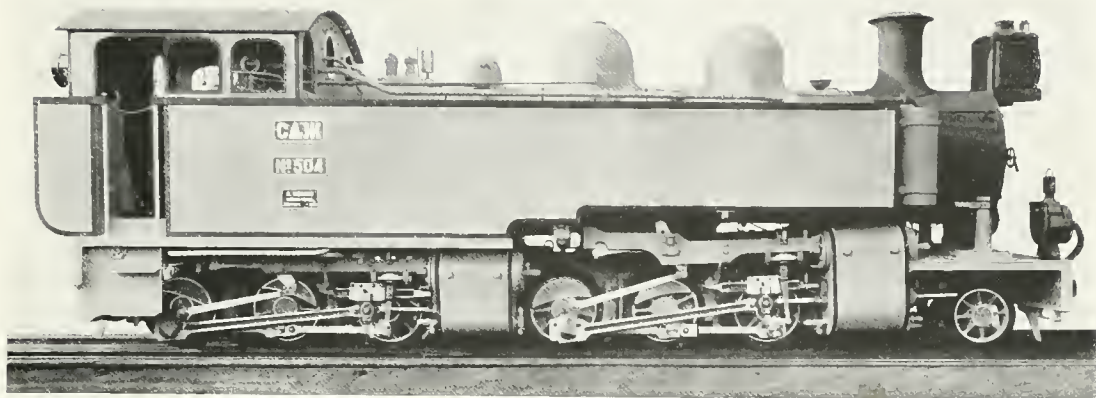
manufacturing, and lumbering wealth. While many of the districts already served by the first transcontinental are tapped, thereby providing competitive routes for shipment, the line also unlocks a vast new territory in central California which is ripe for immediate development.

Oil fuel is to be used upon the mountain division, storage tanks for the supply of the locomotives having been laid down at divisional points. The reservoirs are set up high on the mountain-side so as to secure ample head to ensure a good feed to the locomotives below. This railway, completing the latest American transcontinental, built in accordance with the most recent principles of trunk railway engineering, has cost a matter of £20,000,000. There is no reason why any further capital should be expended upon revising the alignment, at least not for some years to come, so that the initial outlay, while heavy, is complete. A period of five years should be adequate to develop traffic in the country traversed thereby, as settlement has been in progress for several years past, so that the line should soon reach the self-supporting stage.

There was one interesting incident which attended the flight of the first passenger train, carrying the President and his friends from Salt Lake City to San Francisco. At Quiney, about half way through the Feather River Canyon, the train was met by a white-haired gentleman, who, although aged, still was alert, upright and vigorous. This was Mr. A. W. Keddie, who forty-five years before had urged the builder of the first transcontinental to follow the Feather River Canyon, and had been called "mad" for his pains. The old railway pathfinder recalled the stormy interview, and rejoiced enthusiastically that his prediction had been fulfilled, although it had occupied nearly half a century to vindicate his claim that the easiest means of reaching the Pacific seaboard of the United States from the East was by the Feather River Canyon Route.

A Pioneer Justified.

Value of the Line.



NARROW GAUGE (30 INCHES) 2-6-6-0 MALLET LOCOMOTIVE USED FOR PASSENGER AND HEAVY GOODS SERVICE BETWEEN PARATSCHIN AND SAITSCHAR, ON THE SERVIAN STATE RAILWAYS.

Locomotive Giants—V

SOME STRIKING CONTINENTAL AND AMERICAN MONSTERS



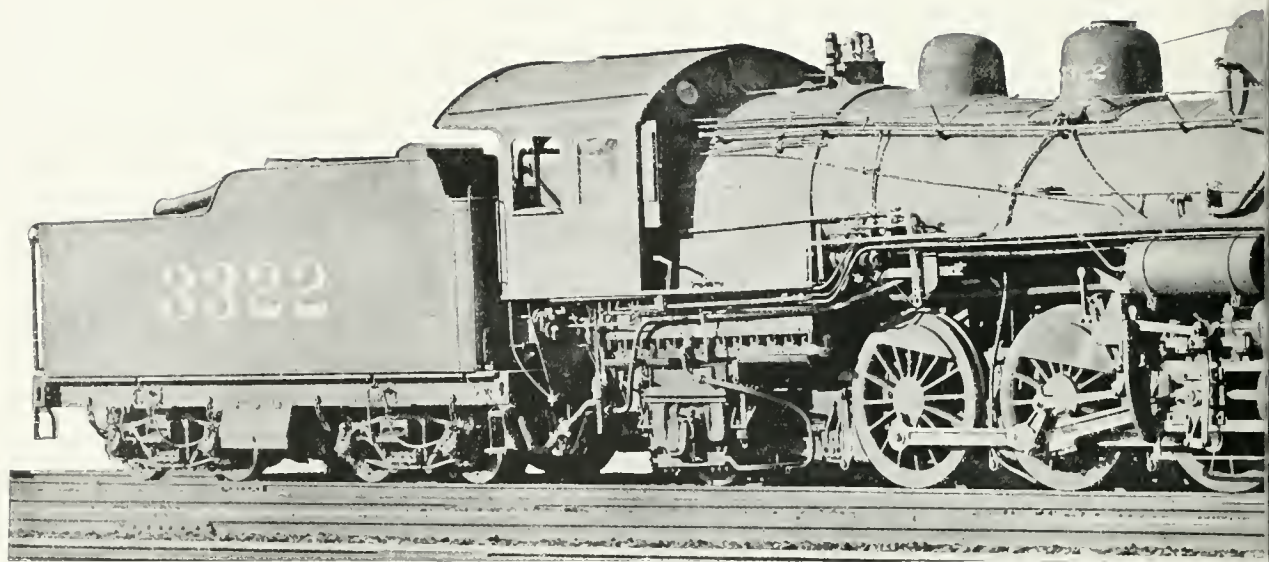
WHEN the Servian Government decided to introduce the Mallet locomotive upon its system, and forthwith called for tenders, the conditions which had to be fulfilled were somewhat exacting. The engines were required for both passenger and heavy goods service upon the line traversing the difficult mountainous country, abounding in heavy grades and sharp curves, between the town of Paratschin and Saitschar, near the Bulgarian border.

The gauge is 760 millimetres—30 inches—and the permanent way permits of a rail pressure of 8 tons. The specification demanded that the tender locomotives should be able without difficulty or trouble to haul a train of 350 tons up a gradient of 1·4 per 100 and a train of 180 tons up a bank of 2·8 per 100, and round S-curves of 195 feet radius, at a speed of 15 kilometres—9·3 miles—per hour. An initial stable of five Mallet locomotives was ordered, and the well-known engineering

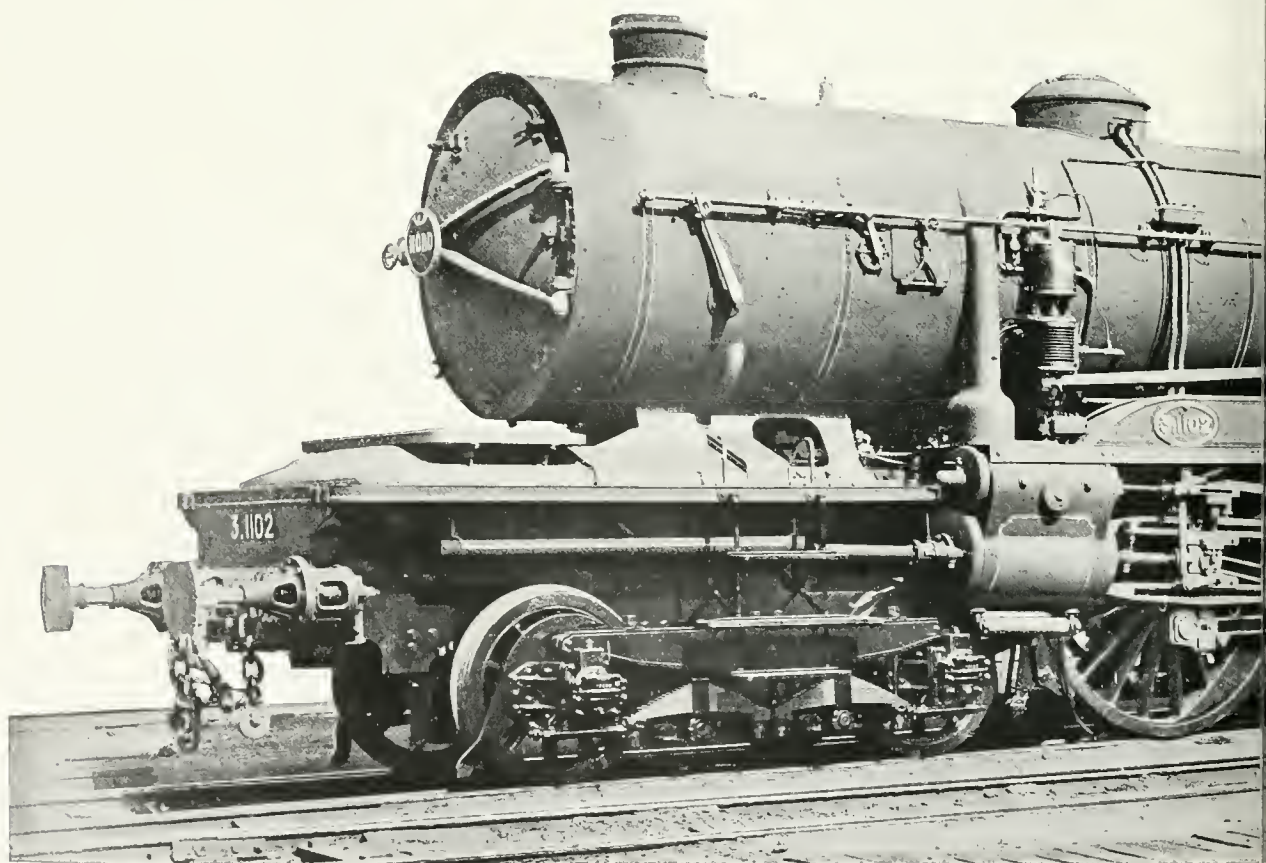
firm of A. Borsig, of Tegel, secured the contract.

The engine is six-coupled. The front axle is connected with the first coupled axle by a Krauss-Helmholtz frame. In the case of the back frame the weight is supported by strong and somewhat rigid springs, but more flexible springs are used for this purpose on the front frame, so that it can adjust itself easily on curves. The members of both frames lie on the inside. The distance between the frames is only 24 inches, and between the bearing centres 20 inches. Despite this small space between the points of support and the high boiler position of 75 inches from the top of rails, the engine runs very steadily, even at a speed of 18·6 miles per hour.

The boiler, for brown coal fuel, is of ample proportions. The tubes measure 13 feet 1½ inches between tube plates, and have an internal diameter of 1½ inches. The grate extends over the frames and wheels, and has a width of 41½ inches

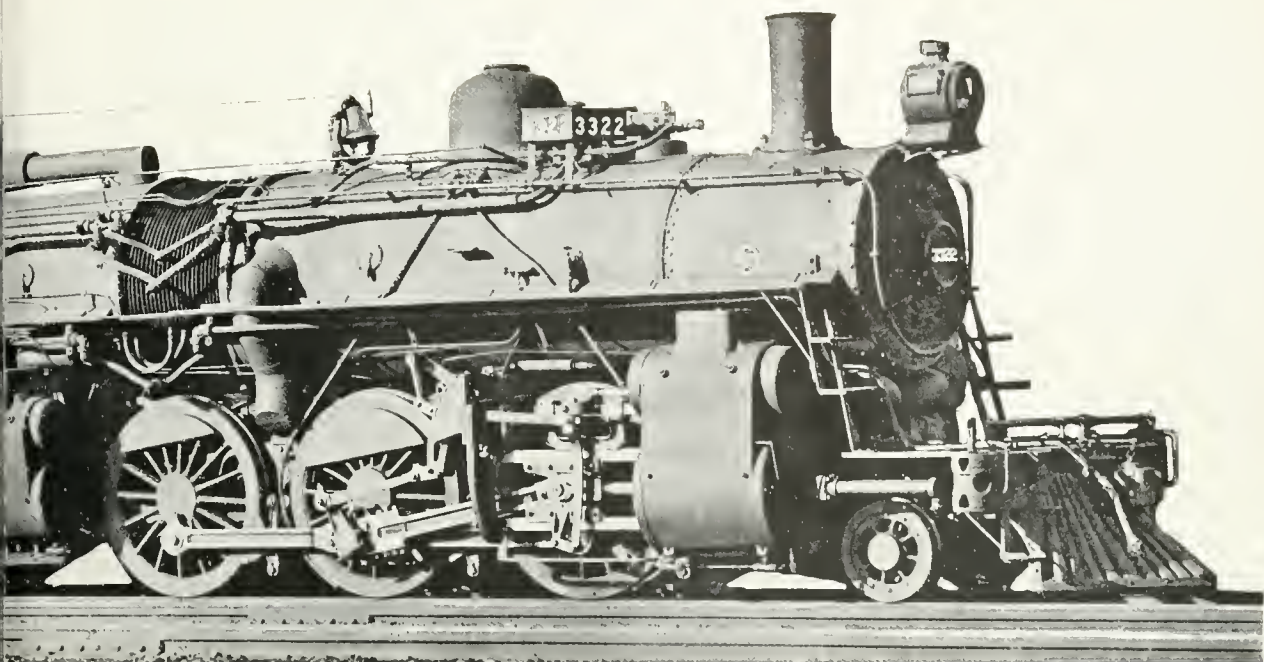


NOVEL FLEXIBLE BOILER BALDWIN MALLETT (2-6-6-2) LOCOMOTIVE BUILT FOR
The boiler consists of two parts united by an "accordion" joint, to facilitate bending upon curves. The

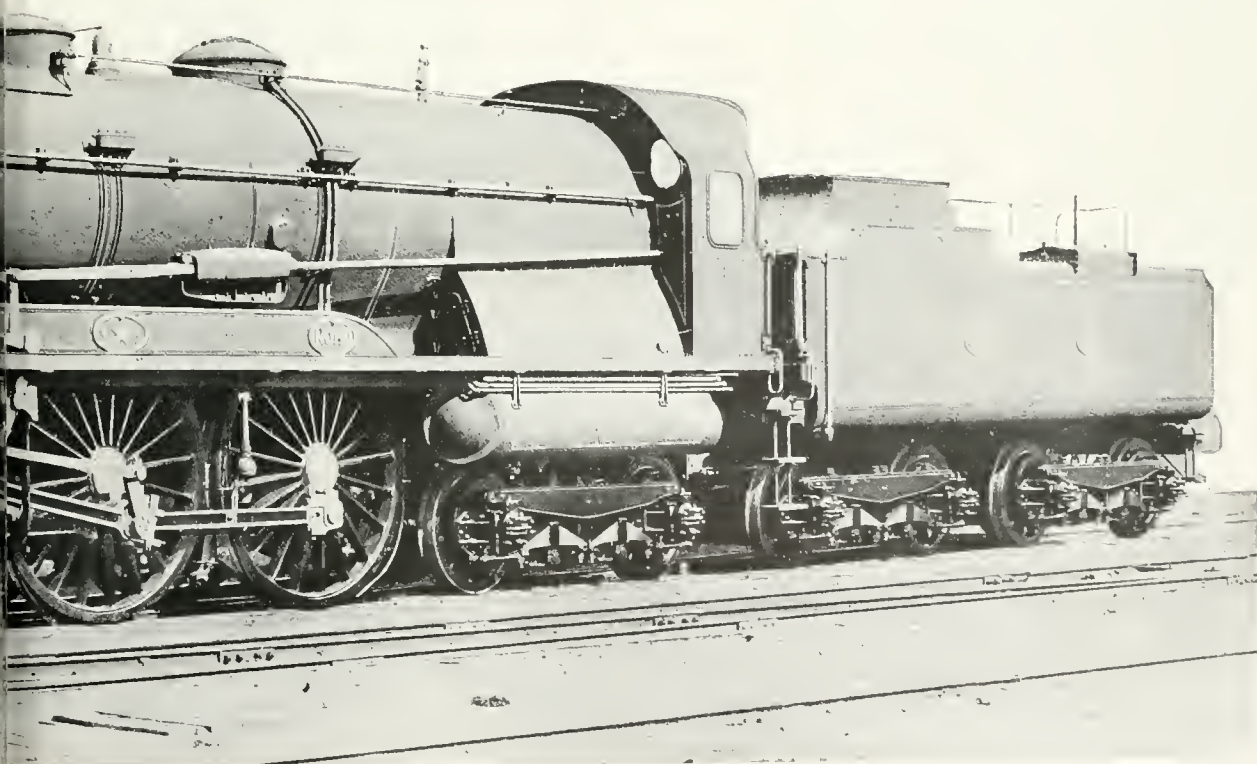


THE HUGE POWERFUL BALTIC (4-6-4)

These engines, which haul the fastest train in the world, weigh $158\frac{1}{2}$ tons upon the rails. They are able to draw



FREIGHT SERVICE UPON THE ATCHISON, TOPEKA AND SANTA FÉ RAILWAY.
front part carries the feed-water heater tubes. In running order the complete locomotive weighs $278\frac{1}{2}$ tons.



LOCOMOTIVE OF THE CHEMIN DE FER DU NORD.

a train weighing 400 tons at 75 miles per hour on the level, and at 60 miles per hour up grades of 1 in 200.

and a length of 71 inches. Owing to the position of the boiler above the rail level an inclined grate and a special furnace arch were necessary.

The high-pressure cylinders have a diameter of 13 inches, while the low-pressure cylinders are $20\frac{1}{2}$ inches in diameter, with a common stroke of $15\frac{3}{4}$ inches. The driving wheels are $31\frac{1}{2}$ inches in diameter. The wheel base is 25 feet 6 inches. The total heating surface is 1,170 square feet, and the grate area 20.5 square feet. Steam is used at a pressure of 190 pounds per square inch. The engine has feed tanks capable of holding 1,200 gallons of water, and bunker capacity for 2 tons. In service conditions the engine weighs 50.9 tons, of which 45.1 tons are available for adhesion.

This firm of locomotive builders also constructed an interesting and powerful locomotive for the Sand Railway Company of Gleiwitz.

Sand Railway Locomotives. There are four collieries in Upper Silesia which are supplied by the above firm with sand, which has to be transported a distance of some 14 miles, the train load comprising 20 self-discharging wagons. This line, of standard gauge, was laid specially for this traffic, and permits a weight of 18 tons upon the rails. The road abounds in curves, and has a maximum gradient of 77 in 100.

The conditions called for a locomotive with a flexible, and not a fixed, wheel-base. The front axle is connected with the first coupled axle by a Krauss-Helmholtz frame, whilst the rear coupled axles have side clearance. The weight of the engine is supported at six main points, the springs being arranged under the axles. The frame is of very solid construction, the main plates having a thickness of $1\frac{3}{8}$ inches. Support at the cylinders is secured by means of plates and angles of box construction. Between the frames is a water tank, which also gives support to the frame.

In order to conform with the admissible

service weight of 96.5 tons, a boiler of very high capacity has been provided. There are 148 boiler tubes and 24 superheater tubes disposed in three rows, and a specially large fire-box, giving a total heating surface of 2,550 square feet. The grate area is 35 square feet.

The diameter and stroke of the cylinder are $25\frac{1}{4}$ inches. The driving wheels are $49\frac{1}{4}$ inches in diameter. The fixed wheel base is 9 feet 6 inches, and the total wheel base 27 feet 6 inches. Steam is used at 180 pounds per square inch. There is capacity for 12 tons of water and $2\frac{1}{2}$ tons of coal.

An unusual expression of the Mallet locomotive is that engaged in the freight service of the Atchison, Topeka, and Santa Fé Railway. In this instance, not only is each set of drivers carried in an individual frame, the two being hinged together, but the boiler itself is flexible, being made in two sections united by a hinge or "accordion" joint, so-called because the connection resembles the bellows of that musical instrument. Both sections of the boiler are rigidly connected to their respective frames, but the provision of the accordion joint permits the boiler to bend when negotiating curves.

This locomotive was built at the Philadelphia shops of the Baldwin Locomotive Company. The high- and low-pressure cylinders have diameters of 24 and 38 inches respectively, the stroke being 28 inches. The steel boiler has a diameter of 70 inches, and works at a pressure of 220 pounds per square inch. There are 290 fire-tubes of $2\frac{1}{4}$ inches diameter by 19 feet 7 inches in length between tube plates; 340 feed-water heater tubes of a similar diameter by 7 feet 8 inches in length, the latter being disposed in the front section of the jointed boiler. The heating surface of the fire-box is 237 square feet; fire-tubes 3,390 square feet; feed-water heater tubes 1,533 square feet;

**A Novel
Baldwin
Mallet.**

and fire-brick tubes 16 square feet, giving an aggregate heating surface of 5,176 square feet, while the grate area is of 63 square feet. The locomotive is also fitted with the Jacobs superheater—318 square feet surface—and reheater—637 square feet surface.

The engine is of the 2-6-6-2 type, the front truck wheels measuring $31\frac{1}{4}$ inches, and the trailers 40 inches in diameter. The outside drivers are 69 and the centre drivers 62 inches in diameter respectively. The weight upon the driving wheels, and consequently available for adhesion, is 157.15 (U.S.) tons, and of the engine in running order 195.9 tons. The 8-wheeled tender has tank capacity for 9,000 gallons of water and 12 tons of soft coal fuel, which, combined with its own bulk, brings the total weight of the complete locomotive ready for the road up to $278\frac{1}{2}$ tons.

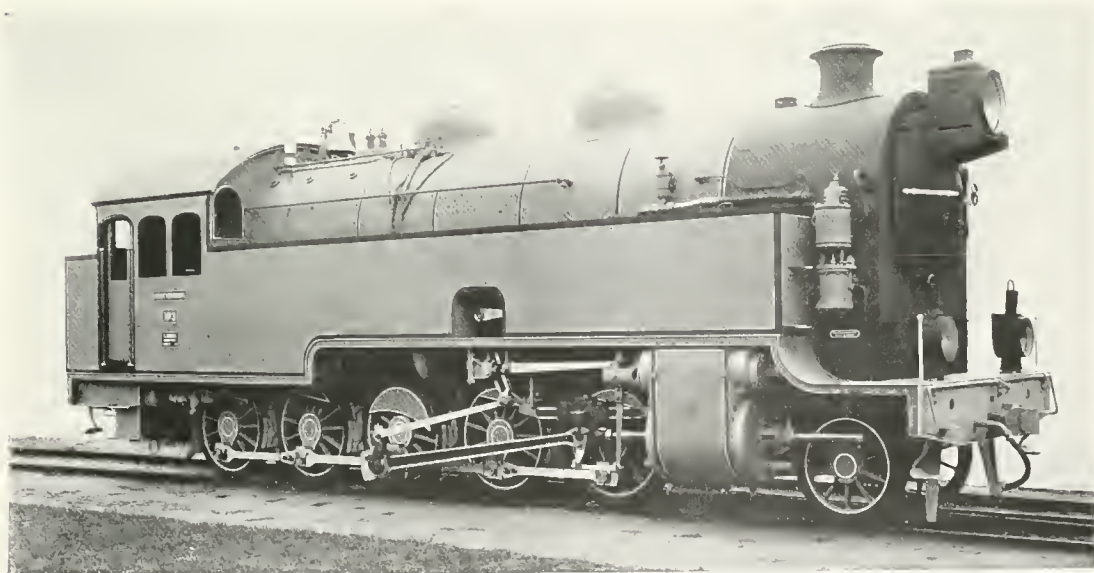
The fastest trains of the Chemin de Fer du Nord of France are handled by powerful Baltics—4-6-4 type—designed by Monsieur Asselin, the mechanical engineer-in-chief to the system. They are compounds, having two high-pressure cylinders each 17.3

inches in diameter and a stroke of 25.19 inches, and two low-pressure cylinders with a diameter of 24.41 inches and a stroke of 28.74 inches. Although superheating is practised, steam is used at a pressure of 227.5 pounds per square inch.

The long boiler barrel has a diameter of $74\frac{3}{4}$ inches. The total heating surface is 4,394.93 square feet, of which the superheating surface is 667.38 feet, with a grate area of 46 square feet. The drivers are $80\frac{1}{4}$ inches diameter, while the bogie wheels have a diameter of $40\frac{1}{2}$ inches.

Ready for the road the engine weighs 102 tons, of which 54 tons are disposed over the drivers, and available for adhesion. The tender is of the Nord standard eight-wheel type, weighing loaded $56\frac{1}{2}$ tons, so that the weight of the locomotive under service conditions is $158\frac{1}{2}$ tons.

With these engines a train weighing 400 tons is able to attain a speed of 75 miles upon the level, some 2,000 horsepower being developed in the cylinders. On grades rising 1 in 200 a speed of 60 miles per hour is sustained.



POWERFUL TEN-WHEEL-COUPLED SUPERHEATED LOCOMOTIVE ENGAGED IN SAND HAULAGE
IN UPPER SILESIA

In running order the engine weighs 96.5 tons.



HOW THE LOW GRADE PAYS.

Heavy freight train upon the Grand Trunk Pacific hauled by a single locomotive.

The Grand Trunk Pacific Railway

THE "ALL-RED ROUTE" ACROSS CANADA, AND ITS REMARKABLY LOW GRADES



THE railway expansion of the Dominion of Canada constitutes one of the outstanding events in modern history. Only thirty years ago "the bounteous West," as it is now colloquially described, stretching from the shores of the Great Lakes to the Rocky Mountains, was a closed book, while scarcely anything was known about the hinterland of British Columbia, which the atlas of the period dismissed as "Unexplored. Travel by canoe and sled only."

This unknown corner of the Dominion has been unlocked by the Grand Trunk Pacific Railway. This transcontinental enterprise compels attention because it was

the conception of a single brain, and still ranks as the biggest individual railway building feat ever attempted. The great steelway of Russia, the Trans-Siberian Railway, excels it in point of mileage between extreme termini, but this was a gradual growth, being completed piecemeal. On the other hand the Grand Trunk Pacific was one homogeneous project, which after the first sod was turned was prosecuted with remarkable zeal, and from a hundred-and-one different points simultaneously.

It appeals to the Canadian people in more senses than one. They have an appreciable financial stake in it. When the scheme was submitted to the Government for approval and assistance, the latter



THE ENGINEER'S CROWNING CONQUEST OF THE MOUNTAINS.

While other railways toil to lofty heights to overcome the Cascade Mountains, the Grand Trunk Pacific threads this range along the Skeena River, with an absolutely level track. It is the fastest line on the North American continent, and the great scenic route of Canada.

recognised a unique opportunity to take a decisive step towards railway nationalisation. The project was split in twain. The eastern section, lying between Moncton, New Brunswick, and Winnipeg, a distance of 1,804 miles, was built by the Government; the second, or western section, of 1,756 miles, reaching from Winnipeg to the Pacific coast, was completed by the Grand Trunk Pacific Railway, an offshoot of the Grand Trunk Railway, organised especially for the purpose. The Government, however, undertook to lease the national section to the private corporation, so that the latter might be possessed of a continuous direct and through communication from Atlantic to Pacific.

This colossal undertaking was forced upon the Grand Trunk Railway by economic considerations recalling those which prompted the building of the Chicago, Milwaukee, and Puget Sound Railway.

The Grand Trunk Railway, which laid the foundations of Canada's commercial prosperity, confined itself to development and expansion in the territory between the Atlantic seaboard and the Great Lakes. In the course of a few years it established a virtual transportation monopoly in this part of the Dominion. When the Canadian Pacific came and unlocked the rolling prairies a surging westward flood of business and traffic set in. This unexpected result hit the Grand Trunk hard. At the outposts of its system it was forced to hand over all western traffic to its young rival, and in return received just what the latter cared to give it, which was very little, because the new road had driven its eastern tentacles into the Grand Trunk's preserves.

The fortunes of the pioneer organisation sank to a very low ebb and bankruptcy appeared imminent. At this juncture Sir Charles Rivers Wilson, whose achievements



A PERIL OF THE RAILWAY BUILDERS IN THE WILDS.

Navvies running a scow laden with constructional material for the Grand Trunk Pacific Railway through the Grand Canyon of the Upper Fraser River.

as an administrator had achieved worldwide distinction, took over the reins of the enterprise, and he at once set to work to unravel the sorry tangle. His first move was the discovery of a strong railway organiser. After a diligent search he found just the type of man he required in Charles M. Hays, who at the time was striving hard to keep a moribund American railway above water, and was proving remarkably successful in his thankless task. He was persuaded to throw his lot in with the Canadian railway. He picked up the threads of the Grand Trunk, and soon got into his stride. Within a few months he had stopped the rot, had cut away considerable dead timber, and had put the road on its feet again.

But from the moment he assumed the direction of affairs Hays realised the true cause of the undertaking's decay. It was suffering from "Transportation cramp." The only real remedy was to give it more elbow room, provide new feeders, and make a strong bid for a share of its opponent's business. To achieve this end a bold extension policy was imperative. He proposed a new transcontinental across the Dominion—not a mere extension from the western outposts of the Grand Trunk to the Pacific, but a complete distinctive line from seaboard to seaboard, through new and untapped territory, with a comprehensive array of spurs and branches carried to competitive points, all of which would serve as feeders to the parent system entrenched in the manufacturing, commercial and financial eastern corner of the country, so that the latter was certain to secure tangible benefits.

This road has been modelled very closely upon the latest expressions of a British main line, with such modifications as local requirements demand. Hays was also an out-and-out believer in the straight level line theory, and accordingly resolved that grades should be far less than anything previously attempted upon the North

American continent, while curves were to be kept well open.

Moncton is the nominal Eastern terminus, although communication with Halifax and St. John is available over the Inter-colonial Railway. From this point **The Route.** it traverses untouched stretches of New Brunswick and Lower Quebec to the south bank of the St. Lawrence, some three miles below Quebec City. The waterway is being spanned by a cantilever bridge which, when completed, will have the longest span in the world. From the north bank the line strikes into the hinterland of Quebec and Ontario, threading immense valuable stretches of timberland.

When the surveying forces entered this country they practically had to act as explorers as well. Maps existed, but they were absolutely untrustworthy, lakes and rivers being shown where they did not exist, and in other cases miles away from their actual position. Penetrating such a forbidding country was attended with considerable risk and adventure. As animals could not be used, the surveyors had to proceed from point to point by means of canoes, which often had to be portaged across many miles of broken and difficult country. In winter an elaborate service of dog trains was inaugurated, which transported provisions to caches, whence the isolated little bands of toilers drew their supplies. The waterways flowing towards Hudson Bay are fiendish and swirling, abounding in treacherous rapids and whirlpools, and claimed their quota of victims, while time after time the surveyors had mad races for life, being smoked out by bush fires which rage with furious violence in this territory.

The constructional armies experienced equal hardships, difficulties and dangers. Hundreds of miles of tête-roads had to be driven, and the waterways and lakes pressed into service as far as practicable. In one instance the contractors laid down 80 miles

of railway to carry in their supplies and tools to build some 14 miles of line. Barges and scows were carried through the bush in pieces to be reassembled upon the banks of a river or lake. Animal haulage was costly inasmuch as every ounce of food

nearly completed, slipped bodily down the incline as if it were a glacier. The water, being unable to escape, owing to the culvert provided therefor having been smashed, piled-up behind the earthworks, which acted as a dam. All efforts to cope with



BUILDING A HIGH EMBANKMENT.

The laden hopper wagons are drawn over the edge, and as they swing down the bottom of the vehicle is opened, thus dumping the contents.

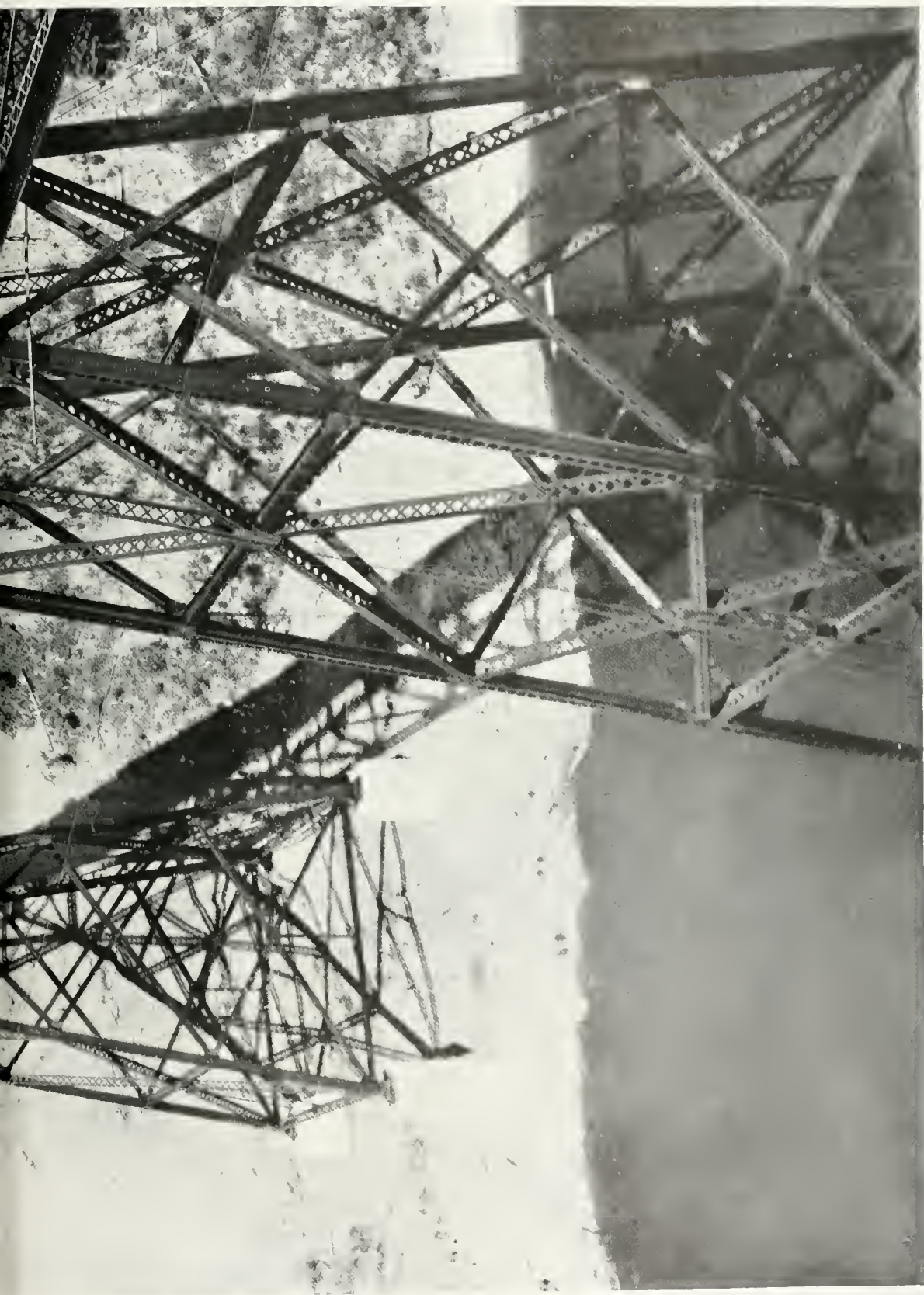
for the mules, oxen, and horses had to be carried in, the country not yielding a blade of grass.

The 1,804 miles of grade between Moncton and Winnipeg were divided into six districts for constructional purposes, while originally 21 contracts were let for the whole of this mileage. The builders were hampered sorely in their work by the treacherous slipping and muskeg. Time after time embankments would collapse when completed, while temporary wooden trestles slid sideways. In one case, where a depression was spanned with a solid earthen embankment, the whole, when

the situation by an embankment proving unavailing, the fill was abandoned in favour of a girder span bridge. The Okekodasik River had been spanned by a massive bridge when suddenly the bank on one side moved bodily, displacing a heavy concrete abutment and an 80-foot girder span. The mass of steel was jacked back into its place, and allowed to rest for the time being upon a timber crib, until a steel trestle approach could be completed.

Owing to the rivers running at right angles to the location, bridging was heavy, while the width of the waterways demanded massive structures. Altogether 200 steel





FREIGHT TRAIN CROSSING THE LOFTIEST BRIDGE ON THE GRAND TRUNK PACIFIC RAILWAY.

In order to cross the Pembina River (Alberta) a lofty steel structure 900 feet in length, and with the rails 213 feet above the water, was necessary.

bridges had to be erected in the course of the 1,804 miles, which if placed end to end would total some 11 miles. For this work an aggregate of 61,000 tons of steel was used at a cost of about £1,200,000, exclusive of the St. Lawrence Bridge.

The earthworks are as impressive in their character as the steel erections. Driving through the rocky fastnesses of

Use of Dynamite. Ontario's uplands made a heavy demand upon explosives. In

one section alone some 13,000,000 sticks of dynamite were used to plough out the grade. In one blast, which took three months to prepare, 3,000 sticks and 200 barrels of gunpowder were fired to move a huge cliff of rock into the lake alongside.

West of Winnipeg the line runs through the richest stretches of the prairie—the famed Qu'Appelle Valley, Carberry Plains, Tramping Lake district, and so forth.

Here construction did not present very marked technical difficulties, except through the more undulating reaches,

Easy Gradients. where heavy cuts and fills were unavoidable in order to preserve

the grade. There is no line upon the North American continent where the grades are so easy. Between Winnipeg and Moncton the heaviest bank rises only 31.68 feet per mile, against east-bound traffic, while between the capital of Manitoba and the Pacific coast the maximum grade is only 21.12 feet per mile against west-bound and 31.68 feet per mile against east-bound traffic respectively. When it is recalled that this Canadian railway has to traverse those two towering barriers, the Rockies and the Cascades, before it makes the western sea, the achievement of the railway plotters in getting through obstacles of this calibre with such low grades may be appreciated fully.

The broad waterways intersecting the prairies, and the deep depressions which they have cut, made a heavy demand upon bridgework. The longest steel structure is the Battle River Viaduct, which has been

described previously, while the loftiest bridge is that spanning the Pembina River. Here a lofty steel bridge 900 feet in length, supported upon two steel towers placed on either side of the river, and bringing the rails 213 feet above the water, was necessary.

The railway enters the Rockies through the gap formed by the Athabasca River cutting through the range.

It crosses the waterway to **Through the Rockies.** enter the narrow Miette Valley,

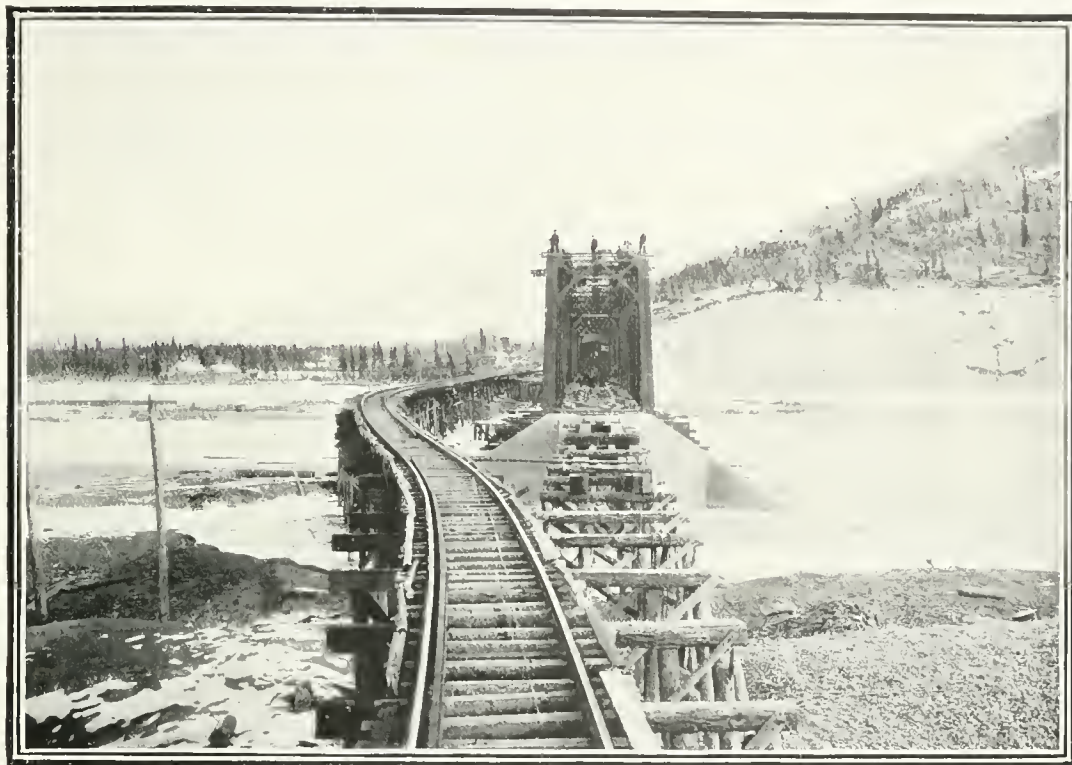
which is ascended, still at 21 feet per mile, to gain the Yellowhead Pass, where the metals notch the highest point throughout the whole 3,560 miles between the Atlantic and Pacific coasts—3,723 feet above sea level, the lowest altitude at which the Rockies are crossed by the steelway.

Crossing the "Pass" the railway picks up and follows the Fraser River as far as the famous Hudson Bay post Fort George, where it parts company with the river to reach Fort Fraser, another Hudson Bay post. Thence it traverses convenient valleys until at last it picks up the Bulkley River, to which it clings until the Skeena River is met at Hazelton. Between Tête Jaune Cache and the Skeena River the railway penetrates the heart of the hinterland of British Columbia, which, from the salubrity of its climate, the richness of its soil, and the prolific produce of all descriptions which can be raised in its well-watered glens, glades, and benchlands, is appropriately styled "The New Garden of Canada." Minerals of all descriptions exist in abundance, and will be worked to profit directly scientific methods of development and operation are installed. The timber wealth also is enormous, huge forests of commercial lumber having been discovered by the surveying forces.

So far as construction down the Fraser River Valley was concerned, the difficulties encountered were rather of a transportation character. Everything was brought in from the east to Tête Jaune Cache, and there transferred to steamboats. These

were built on the river bank at Soda Creek, 220 miles from the nearest railway station, to which point the machinery was hauled overland at a cost of approximately £50 per ton. Between Fort George and Tête

way plotter many teasing problems of no mean order, and hitherto have been overcome only by recourse to remarkably ingenious development work, with stupendous grades and toils to extreme heights. But



THE CROSSING OF THE ATHABASCA RIVER NEAR THE YELLOWHEAD PASS.

While the massive steel structure was under erection the line was carried across the waterway over a trestle to enable construction trains to reach the railhead.

Jaune Cache there are 350 miles of waterway navigable by small steamships, wherewith the rapids and canyon may be run in safety. The availability of the river communication enabled construction to be carried out simultaneously over the whole distance between Tête Jaune Cache, Fort George and Fort Fraser, a water distance of some 600 miles.

But the most spectacular illustration of engineering afforded upon the Grand Trunk Pacific is the negotiation of the Cascade Mountains. This range presses hard on the seaboard, the outer ramparts in fact tumbling sheer into the water. Farther south these mountains offered the rail-

the Grand Trunk Pacific traverses the range without as much as a rise of 1 foot per mile! For 60 miles out of Prince Rupert the line is dead level, and in this distance the backbone of the mountains is overcome. It was rendered possible because the plotters ran a location along the north bank of the Skeena River, which cuts at right angles through the barrier.

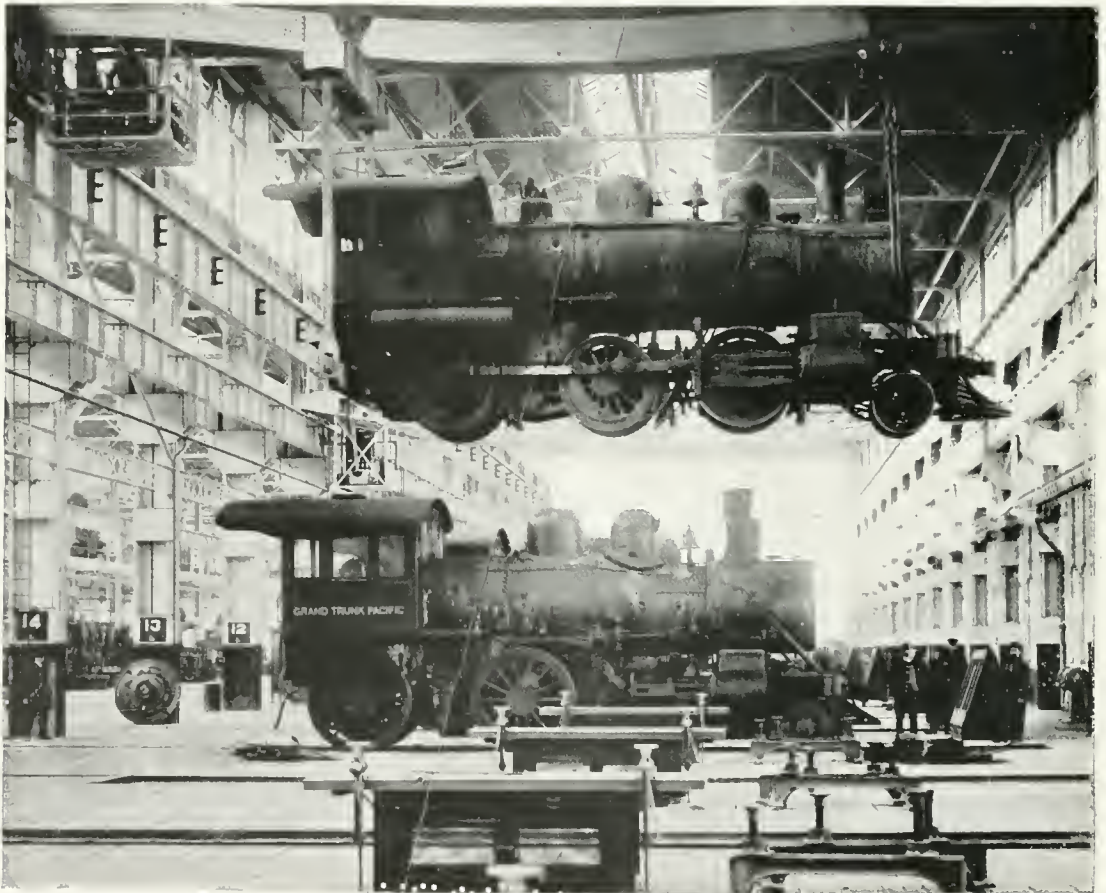
When the line was taken in hand it was decided to create a new port upon the Pacific seaboard. Vancouver stood as the solitary marine centre of British Columbia, but there was one large indentation, 550 miles north of Vancouver, known as Tuck's Inlet, which it was decided to exploit.

Tuck's Inlet, re-christened Prince Rupert, offers the finest natural harbour on the Pacific coast north of San Francisco, and is as capable of development as Halifax on the Atlantic seaboard. The harbour is about 10 miles in length, with an entrance about half a mile in width, opening out to an extreme width of $1\frac{1}{2}$ miles, and with water shelving from 30 to 300 feet.

The creation of a new port and the Pacific terminus of the Grand Trunk Pacific at Prince Rupert was an astute move. It gave the railway an independent outlet and ample elbow room for future developments. Here a busy maritime city is being moulded. Geographically it is a strategical centre, because it is some 500

miles nearer China and Japan than its rival, Vancouver. Consequently the "All Red Route" via the Grand Trunk Pacific Railway represents at least the saving of one day's steaming across the Pacific, an advantage of importance in these days of hustle.

As an example of railway engineering the Grand Trunk Pacific stands unique. It is not a pioneer road, but a trunk line created as such in the beginning, according to modern interpretations. The standard of construction has been high, but this has been imperative in order to meet present-day requirements, where the saving of minutes and the annihilation of distance constitute the vital considerations of travel and traffic.



SLINGING A 100-TON LOCOMOTIVE.

The Transcona shops of the Grand Trunk Pacific Railway are among the best equipped in the world. By means of an overhead electric crane engines weighing up to 120 tons can be lifted and moved.

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be "about 72 miles per hour."
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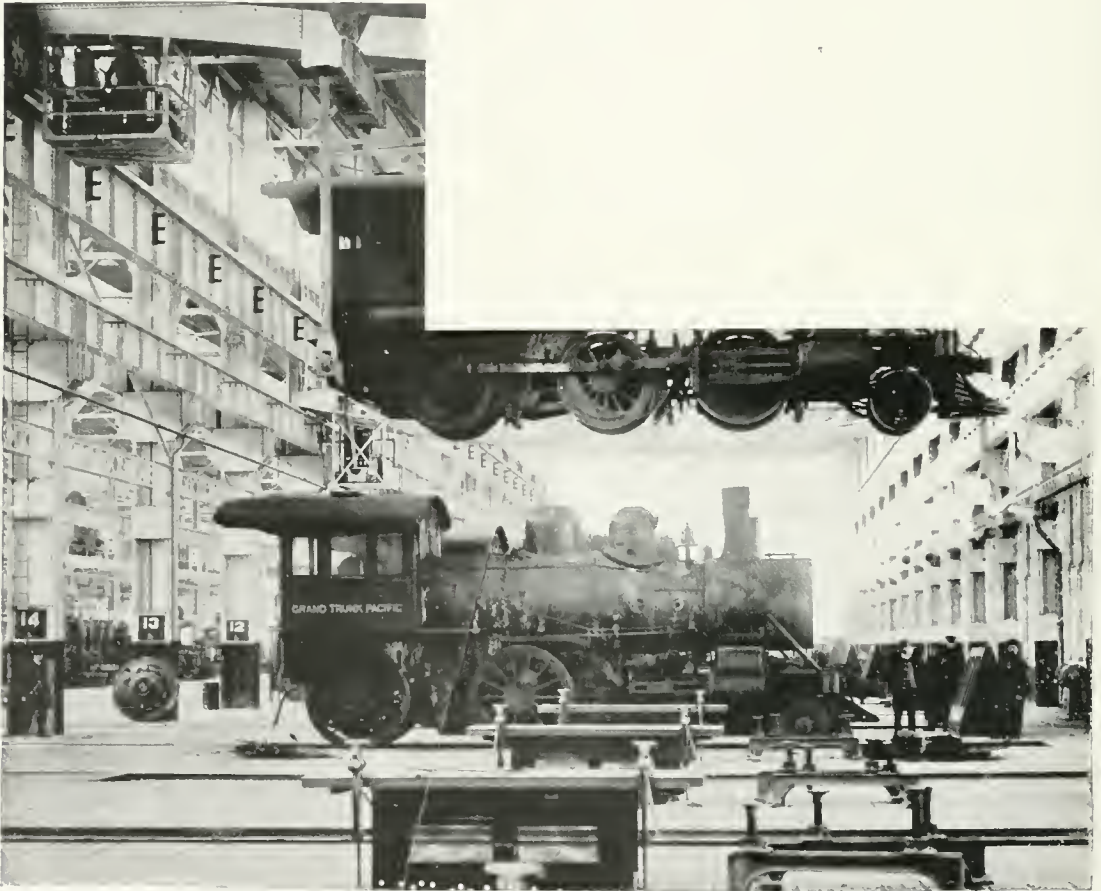
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Tuck's Inlet, re-christened Prince Rupert, offers the finest natural harbour on the Pacific coast north of San Francisco, and is as capable of development as Halifax on the Atlantic seaboard. The harbour is about 10 miles in length, with an entrance about half a mile in width, opening out to an extreme width of $1\frac{1}{2}$ miles, and with water shelving from 30 to 300 feet.

The creation of a new port and the Pacific terminus of the Grand Trunk Pacific at Prince Rupert was an astute move. It gave the railway an independent outlet and ample elbow room for future developments. Here a busy maritime being moulded. Geographically strategical centre, because it is s

miles nearer China and Japan than its rival, Vancouver. Consequently the "All Red Route" via the Grand Trunk Pacific Railway represents at least the saving of one day's steaming across the Pacific, an advantage of importance in these days of hustle.

As an example of railway engineering the Grand Trunk Pacific stands unique. It is not a pioneer road, but a trunk line created as such in the beginning, according to modern interpretations. The standard of construction has been high, but this has been imperative in order to meet present-day requirements, where the saving of



SLINGING A 100-TON LOCOMOTIVE.

The Transcona shops of the Grand Trunk Pacific Railway are among the best equipped in the world. By means of an overhead electric crane engines weighing up to 120 tons can be lifted and moved.

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